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

Work Package 11

TA1 - Facilities for Improved Component Characterisation and Micro Grid Validation

Deliverable D11.1

D-TA1: "Summary Report of TA1 Activities"

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Abbreviations

CHIL	Controller Hardware-in-the-Loop
DER	Distributed Energy Resource
DRTS	Digital Real-time Simulator
HTD	Holistic Test Description
PC	Project Coordinator
PHIL	Power Hardware-in-the-Loop
RI	Research Infrastructure
UG	User Group
UP	User Project
SuT	System under Test
TA	Transnational Access
WP	Work Package

Executive Summary

This report presents the main outcomes of the ERIGrid TA1 Work Package “Facilities for improved component characterisation and Micro Grid validation”. The research infrastructures organised under TA1 supported and hosted 41 Transnational Access (TA) projects through a collaborative programme of experiments coordinating nine of the ERIGrid consortium’s leading research infrastructures (RIs) and providing free access to EU and international user groups. The TA projects covered a wide spectrum of characterisation and validation activities for smart grid components and systems, including but not limited to control concepts, machine learning algorithms, micro-grid operation and systems integration.

This report firstly presents an overview of the hosted projects, and then identifies exemplary projects which have been shortlisted from the completed thirty-nine projects, based on host Research Infrastructure feedback. For each project, the user group is introduced and some of the main outcomes benefiting the user groups are presented.

Secondly, the report provides a summary of the main outcomes highlighting the impact of the TA1 activities on the host and user groups including technical and organisational lessons learned. Finally, the report presents a set of recommendations which have been drawn from the learnings of the research infrastructures hosting TA projects during ERIGrid TA1, with a view to enhance the TA experience and advance systems testing procedures in the following ERIGrid 2.0 project.

1 Introduction

Transnational Access (TA) activities are at the core of the ERIGrid project where European and international user groups are granted free access to the leading smart grid Research Infrastructures (RI) of the ERIGrid consortium members in order to carry out research and testing projects. Details and statistics about the whole TA programme can be found in the deliverables D3.4 [1] and D3.5 and [2]. This report focuses on the lessons learned from infrastructure implementation of user projects undertaken as part of the TA1 Work Package “Facilities for improved component characterisation and Micro Grid validation” of the ERIGrid project. This work package aims to facilitate the access provision to outstanding facilities for component characterisation and for validating small-scale systems such as islands, micro grids, or low-voltage networks. Expected user projects activities included characterizing components and small-scale systems, but also co-simulation and HIL. Some user projects utilized enhancements of methods and tools of the research infrastructure developed in ERIGrid networking and joint research activities, including the harmonization of the distributed infrastructure provided by the ERIGrid partners.

1.1 Purpose of the Document

This document aims to present a summary of the learnings from the practical support of these access activities. To this end it presents:

- A quantitative and qualitative overview of successfully hosted user projects under TA1,
- Highlights of the impact of TA1 activities for the user groups and the ERIGrid community,
- Lessons learned from the TA1 activity in general, the experimental implementation and other logistical issues of delivering TA1 activities, and
- Recommendations for concrete improvements to TA1 related procedures and experimental practice where appropriate.

1.2 Scope of the Document

This report focuses on the findings, impact and lessons learned from the activities associated with the user projects carried out in the Research Infrastructures organised under TA1. For TA2, which aimed to provide access to facilities supporting the evaluation of large-scale systems (e.g., on distribution grid level) as well as allowing to analyse system integration questions, a separate report has been published as deliverable D12.1 [3].

1.3 Structure of the Document

This report firstly presents an overview of completed TA1 projects in Section 2. This is then followed by a brief overview of selected projects and their outcomes in Section 0. These projects were selected with the aim of highlighting the main impacts TA1 projects have had on the user groups and on the ERIGrid community. Several reflections and recommendations from the TA1 activities are presented in Section 4 with a view to improve the project experience and enhance their impact going forward in the ERIGrid 2.0 project.

2 Overview of TA User Projects Realised in TA1 Facilities

This section includes summary statistics of the utilization of TA1 facilities and a complete list of the user projects carried out. The facilities organised under TA1 are described in detail in deliverable D-NA3.1 [4] and are not further discussed here.

2.1 Facilities

User projects were hosted in all facilities organised under TA1. Table 1 summarises the utilisation of user projects' host infrastructures. The reported access days of user groups was somewhat balanced according to the expectations. A few partners offering several RIs experienced higher interest in one facility than another. Details on the access projects, user group information and statistics are found in [1] and [2].

Table 1: Overview of user projects per RI

RI Name	***Nº of User Projects***	***Sum of Nº of Users in the Installation***	***Sum of Nº of Access Days***
CEA: PRISMES	2	2	50
CRES: DG-Lab	5	10	60
DTU: SYSLAB/ICL	7	15	73
ICCS: EESL	8	19	116
SIN: NSGL	5	10	57
TEC: SGTL	6	20	83
UST: D-NAP	6	14	65
VTT: SG-Oulu	2	3	10
Grand Total	*41*	*93*	*514*

2.2 User Projects

An overview of the user projects completed under TA1 is found in Table 2. The 41 executed TA1 user projects included user groups from 22 countries whereas 3 Multi-RI projects have been realized, which involved facilities organised under both TA1 and TA2. The detailed results of these user projects have been described in individual reports which are all accessible via the ERIGrid website[1].

Table 2: User projects realised in TA1 (projects reported herein are highlighted)

TA User Project Ref. No.	***TA User Project Acronym***	***Lead Organisation***	***Type***	***Country***	***Host RI***	***Nº of Users in RI***	***Nº of Access Days***
01.001-2016	TEAM-VAR	ETH Zurich	HE	Switzerland	DTU: SYSLAB/ICL	3	15
01.004-2016	DiNODR	Istanbul Technical University	HE	Turkey	DTU: SYSLAB/ICL	2	15
01.005-2016	*FT Operation*	*University of Liverpool*	*HE*	*UK*	*ICCS: EESL*	*1*	*15*

[1] TA user project results, including publications: https://erigrid.eu/transnational-access/selected-projects/

TA User Project Ref. No.	*TA User Project Acronym*	*Lead Organisation*	*Type*	*Country*	*Host RI*	*Nº of Users in RI*	*Nº of Access Days*
01.006-2016	REPRMs	National Institute of Technology Warangal	HE	India	SIN: NSGL	2	6
01.007-2016	DUSCP	Aalborg University & Dicle Üniversity	HE	Denmark & Turkey	CRES: DG-Lab	1	17
01.011-2016	*NOMADIC*	*Politecnico di Milano*	*HE*	*Italy*	*ICCS: EESL*	*4*	*20*
01.014-2016	Eval-loggers	University Paul Sabatier (Toulouse 3)	HE / RInst	France	ICCS: EESL	3	10
02.001-2017	Multi-Island	Democritus University of Thrace	HE	Greece	TEC: SGTL	3	19
02.002-2017	DERT4PM	University of Greenwich	HE / RInst	UK	ICCS: EESL	1	18
02.005-2017	*ECOSMIC**	*University of Antwerp*	*HE*	*Belgium*	*CRES: DG-Lab*	*1*	*5*
02.005-2017	*ECOSMIC**	*University of Antwerp*	*HE*	*Belgium*	*DTU: SYS-LAB/ICL*	*1*	*5*
02.005-2017	*ECOSMIC**	*University of Antwerp*	*HE*	*Belgium*	*VTT: SG-Oulu*	*1*	*5*
02.006-2017	ROCOF	Institute of Physical Energetics (IPE)	RInst	Latvia	SIN: NSGL	2	5
02.008-2017	*TCMG*	*Ecole Polytechnique Fédérale de Lausanne (EPFL)*	*HE*	*Switzerland*	*SIN: NSGL*	*1*	*14*
02.011-2017	DD-CVC	Nanyang Technological University	HE	Singapore	UST: D-NAP	2	11
02.012-2017	LMSWT-Nepal	Kathmandu Alternative Power and Energy Group (KAPEG)	RInst	Nepal	ICCS: EESL	3	10
02.013-2017	HARMONIC	Democritus University of Thrace	HE	Greece	UST: D-NAP	2	9
03.001-2017	*IDR*	*University of Palermo*	*HE*	*Italy*	*CEA: PRISMES*	*1*	*28*
03.005-2017	DAMS4IRMA	Politecnico di Milano	HE	Italy	DTU: SYS-LAB/ICL	4	10

TA User Project Ref. No.	***TA User Project Acronym***	***Lead Organisation***	***Type***	***Country***	***Host RI***	***Nº of Users in RI***	***Nº of Access Days***
03.006-2017	*SPEARHEAD*	*LAAS – Laboratory of Analysis and Architecture of Systems*	*HE / RInst*	*France, Argentina, Germany*	*ICCS: EESL*	*4*	*9*
04.002-2018	WMPOMS	G.B. Pant Institute of Engineering and Technology, Pauri Garhwal (India)	HE / Utility (TSO)	India, Norway, Finland	SIN: NSGL	2	14
04.004-2018	ASM SPS	University of Liverpool	HE	UK	ICCS: EESL	2	19
04.009-2018	LiBRE	Enfinity Belgium	Ind	Belgium	CRES: DG-Lab	1	20
04.013-2018	LCC	WalOpt SCRL	Ind	Belgium	CRES: DG-Lab	3	5
04.014-2018	D-POVERED	Washington State University	HE	USA	UST: D-NAP	1	17
04.018-2018	TEAM-VAR 2	ETH Zurich	HE	Switzerland	DTU: SYS-LAB/ICL	1	10
04.019-2018	Open DISCO	Universität Hamburg	HE	Germany	UST: D-NAP	2	8
04.022-2018	*PERSEID*	*Universidad Carlos III de Madrid*	*HE*	*Spain*	*SIN: NSGL*	*3*	*18*
04.023-2018	PV Systems	University of Agder	HE	Norway	ICCS: EESL	1	15
04.024-2018	COHERE	Chalmers University of Technology	HE	Sweden	VTT: SG-Oulu	2	5
04.025-2018	*ProMeter-Interface**	*AGH University of Science and Technology*	*HE*	*Poland*	*CRES: DG-Lab*	*4*	*13*
05.001-2018	IsDHDG	NIT Raipur	HE	India	TEC: SGTL	2	15
05.002-2018	Standard-Charge	Fukushima Renewable Energy Institute, AIST (FREA)	RInst	Japan	UST: D-NAP	2	10
05.008-2018	*HOLISTICA*	*Ingelectus Innovative Electrical Solutions SL*	*Ind*	*Spain*	*DTU: SYS-LAB/ICL*	*2*	*6*

TA User Project Ref. No.	***TA User Project Acronym***	***Lead Organisation***	***Type***	***Country***	***Host RI***	***Nº of Users in RI***	***Nº of Access Days***
05.015-2018	ARTUPS	NIT Raipur	HE	India	TEC: SGTL	2	15
05.019-2018	*PV Inv Char*	*Council for Scientific and Industrial Research (CSIR)*	*RInst*	*South Africa*	*CRES: DG-Lab*	*1*	*22*
05.021-2018	*VILLAS4-ERIGrid**	*RWTH Aachen University*	*HE*	*Germany*	*DTU: SYS-LAB/ICL*	*2*	*12*
05.024-2018	MGCS-LTV	AIT Austrian Institute of Technology	RInst	Austria	TEC: SGTL	2	17
06.007-2019	VALERIA	elena international GmbH	Ind	Germany	TEC: SGTL	5	10
06.009-2019	H2AI	LAAS – Laboratory of Analysis and Architecture of Systems	RInst	France	UST: D-NAP	5	10
06.011-2019	*Z-NET – ERIGRID*	*HES-SO Valais-Wallis*	*HE*	*Switzerland*	*TEC: SGTL*	*6*	*7*
RI Visits Total	*41*				*sum (avg) | sum*	*93 (2.3)*	*514*

Legend: * - Multi-RI project; HE – Higher Education, RInst – Research Institute, Ind – Industry

3 Exemplary TA User Projects

This section identifies and presents several exemplary projects to allow the highlighting of learnings from the TA1 activities. Each of the selected projects is associated with some relevant impact for the smart grid *industry*, *academia* (research and education), and *RI communities* (testing methods and procedures).

Several projects contributed to all three categories but need only be introduced once in the following sections. The introduction is kept simple, as detailed documentation is available on all TA projects through Technical Reports, Fact Sheets and publications – which are all referenced on https://erigrid.eu/transnational-access/selected-projects/.

3.1 Selection of Exemplary Projects

User projects were selected in TA1 by the participating host RI. The selection criteria included:

1. Alignment with ERIGrid scientific objectives:
   a. Utilisation of holistic testing procedures and test description methods
   b. Co-simulation and/or Laboratory coupling methods
   c. Supporting education and training, publication of results
2. Examples of Multi-RI access and resulting learnings for harmonization
3. Highlights of industry user groups and industry-academic collaboration user groups
4. Value creation for non-EU user groups

Table 3 presents the selected projects and notes which criteria motivated their selection.

Table 3: List of selected exemplary user projects

#	TA User Project Ref. No.	TA User Project Acronym	Criteria and Motivation for Selection	User Group Classifica-tion*
1	01.005-2016	FT Operation	Insights on operational procedures under faults and the control of AC/DC/AC converter in CHIL setup; contribution to user group educational programs; high-profile publications	A
2	01.011-2016	NOMADIC	Essential inputs for user PhD project; publications; Improvements on host RI capabilities	A, (RI)
3	02.005-2017	ECOSMIC	First Multi-RI TA (4 RIs in total; 3 in TA1); Microgrid theme; journal publication	A, RI
4	02.008-2017	TCMG	Technical/procedural learning for RI host; insights for TA coordination in ERIGrid 2.0; validated publication.	A, RI
5	03.001-2018	IDR	Supporting education and training (user's PhD thesis); journal publication	A
6	03.006-2017	SPEARHEAD	High-impact, prize-winning open source SW/HW developments; learnings for host RI; lead to follow-up PhD projects.	I / A, RI
7	04.018-2018	TEAM-VAR 2	Top research quality, theoretical results for first time validated in the lab; RI host learnings.	A, (RI)
8	04.022-2018	PERSEID	Value from HTD application evident; relevant for ERIGrid 2.0; published results.	A, RI
9	05.008-2018	HOLISTICA	Industry collaboration example with complex lab setup, close to a field test; learnings for RI host; publication	3x I

#	*TA User Project Ref. No.*	*TA User Project Acronym*	*Criteria and Motivation for Selection*	*User Group Classifica-tion**
10	05.019-2019	PV_Inv_Char	Projects that demonstrates value of EU RI to non-EU users (UG from South Africa), skills-transfer; learning for RI Host.	P
11	05.021-2018	VILLAS4-ERIGrid	Multi-RI project; results on RI enhancements relevant for ERIGrid 2.0; publications (conf. and journal)	A, RI
12	06.011-2019	Z-NET	User group is a combination of universities and a DSO (SIG Genève), and strong interest of an industrial com-pany, which was present in the lab during the experi-ments.	A / I / P

(*) User group categories: (I)ndustry, (A)cademic, (P)ublic Sector, (RI) – Research Infrastructure Relevance

3.2 Exemplary Projects with Industrial Relevance

The projects SPEARHEAD, HOLISTICA, PV_INV_Char, and Z-NET are identified as of interest to industrial users of ERIGrid RI. Each of the projects has a unique profile of interest.

Behind the project HOLISTICA was a consortium of 3 commercial entities including a hardware man-ufacturer (MV/LV OLTC Transformer), system integrator, and control solutions provider. The user project characterized the coordinated control solution for its effectiveness on several metrics in com-parison with alternate control strategies as shown in Figure 1.

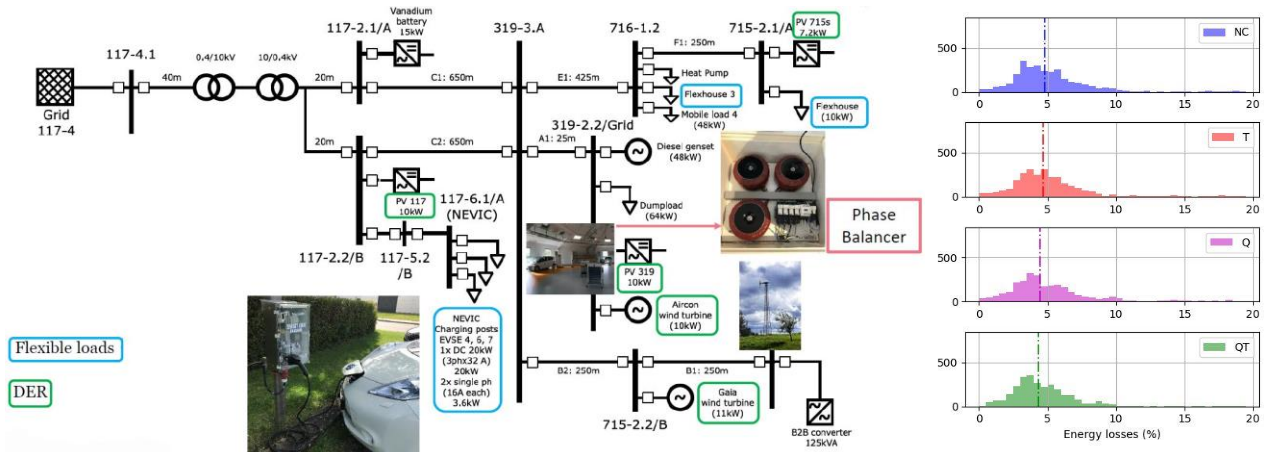

Figure 1: One of the HOLISTICA hardware experiment setups in SYSLAB and test results on loss reduction for 4 control strategies (Source: Presentation 10 in [5])

The PV_INV_Char user project was proposed and led by a public research institute from South Africa, developing a procedure and PHIL test bench for validation and certification of PV inverters with respect to a wide range of standards. It allowed the user group to design the first certification platform for PV inverters in South Africa, which is an important technology transfer achievement helping PV industry development.

SPEARHEAD is mainly led as an academic user group with a focus on open innovation, including open software and open hardware designs aimed at modular power electronics designs for rural electrification. One of the impacts from this user project was that the software validated during the TA allowed the user group to get the second place at the TAPAS challenge organised by Siemens[2].

[2] More on the "TAPAS challenge" *here*, and the TAPAS software defined inverter *here*.

Z-NET was a collaboration of a public research institute with a utility, which was closely followed by an industrial technology provider. It could be demonstrated, in practice, that the Frequency Dependent Grid Access Impedance (FDGI) can result in PLC signal attenuation.

3.3 Exemplary Projects with Academic Relevance

The projects FT Operation, NOMADIC, IDR, SPEARHEAD, TEAM-VAR 2, and have been identified as of interest with respect to academic users of ERIGrid RI. All projects achieved a good academic record, and each of them has a unique profile of interest.

Typical for projects with academic relevance is the contribution to PhD education, novelty in test design, and research objectives aiming at high-impact publications. Another common fact is the related low maturity of the initial algorithm designs, which strongly rely on RI hosts offering adapted deployment infrastructure, such as MATLAB interfaces and support in the design of testing campaigns.

The IDR UP allowed the UG to validate their novel droop control algorithm. The result forms an important part in the user's thesis and is the subject of one journal publication. Knowledge transfer has also been achieved as the UG has plans to setup a real-time simulation and PHIL platform in their lab.

The TEAM-VAR 2 project was a follow-up of the earlier TEAM-VAR TA with the same UG leader, in which important learnings on theoretically designed distributed control algorithms were realised. The TEAM-VAR 2, performed by a first-year PhD student, allowed to both validate the theoretical benefits of the improved algorithm and to achieve a realistic fully distributed implementation in collaboration with the hosting RI, leading to two high-profile publications.

The FT Operation UG learnt to establish power circuits models for DRTS simulations, it addressed typical issues emerging from the validation of control algorithms in realistic test environments and implemented and verified control algorithms in CHIL. As outcomes, several high-profile publications were achieved.

The NOMADIC project achieved the validation of new optimization algorithms for microgrid energy management through experimental implementation. The experiments were possible due to equipment that was not available at the user group's own facilities and enabled the user to successfully complete his PhD thesis.

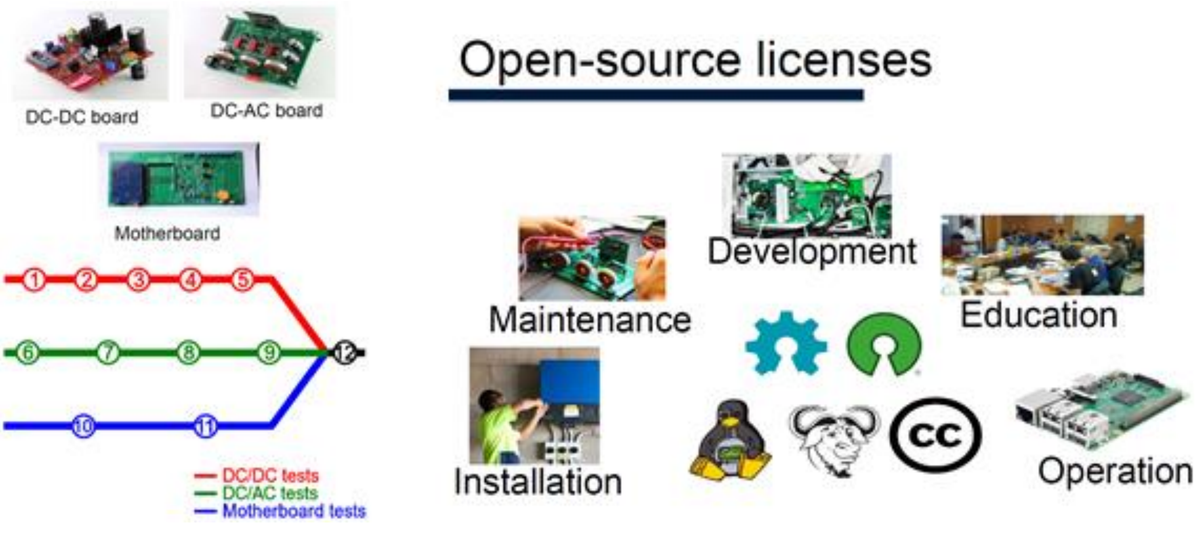

Figure 2: Hardware elements and graphical test plan of SPEARHEAD project (left); overview of open-source contributions of SPEARHEAD and related user projects (Source: Presentation 11 in [5]).

In other academic impacts, the above-mentioned SPEARHEAD TA marked a turning point in research regarding modular power electronics. Since then it has fuelled 5 different internships and allowed the user group to structure a PhD thesis in the field of statistical learning for modular power electronics applied to rural electrification.

3.4 Exemplary Projects of Relevance for RI Development

In this category, the projects ECOSMIC, TCMG, PERSEID, and VILLAS4ERIGrid have been selected for their impact on RI development within ERIGrid and beyond the project. The highlights of these projects in that context include both technical developments and advancements to the services delivered by the hosting RI.

Two of these projects are Multi-RI projects: ECOSMIC visited a total of 4 ERIGrid RIs of which two are in TA1 (CRES and DTU). VILLAS4ERIGrid was hosted in one TA1 RI (DTU) and one TA2 RI (TU Delft). It is a common characteristic of Multi-RI access projects that the same user group meets a variety of different laboratories and experiences varied staff competences. The reflection on the expectation of user groups and achieved outcomes allowed the RI hosts to align their respective understanding and service offers.

In case of the ECOSMIC TA, the UG consisted of an academic group, represented by a PhD student with non-technical academic background whose research aimed at a comparative economic evaluation of microgrid operation concepts and strategies. This UP relied strongly on the capacities of the respective RI hosts to build such typical operating strategies applying their respective national frameworks and technical preferences to execute several 24h runs of microgrid operation. The RI hosts here developed use case details, the technical solution and the testing strategies *as a service*, and further they served as interview partner for the UG. The data thus gathered from interviews and experiments were integrated by the user to feed and validate an economic model for the PhD project, which is also described in a journal publication.

The UP VILLAS4ERIGrid involved a collaboration of an external UG with two ERIGrid partners, where both ERIGrid partners participated in the respective other RI experiments, leading to a mutual learning effect on the ERIGrid community. The research objectives of the UP were fully aligned with ERIGrid objectives with the focus on extending RI capabilities for geographically distributed real-time simulation as well as geographically distributed PHIL. The TA1 part of this UP was focussed on extending on previously unpublished concepts developed in ERIGrid D-JRA3.2 on quasi-static PHIL and monitoring concepts. The experiment setup is illustrated in Figure 3.

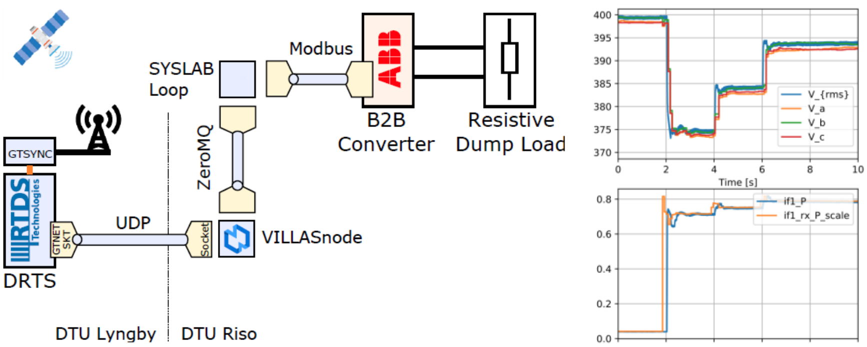

Figure 3: Experiment setup of geographically distributed quasi-static PHIL, with test results from a compensated case (VILLAS4ERIGrid at DTU (Source: Presentation 13 in [5])

The TCMG project included two experiments, one about the design of current controllers for multiple parallel inverters, and one to validate a distributed control approach. Both experiments required a PHIL setup, combining a DRTS simulation with two to three real inverters, allowing to achieve realistic results that include many nonlinear effects and dynamics that are very hard to model in simulation. The RI host learned how to solve PHIL stability problems and that providing templates (e.g. RTLAB Simulink files) for the users before their arrival leads to optimal use of time in the lab.

The PERSEID TA projects benefitted from the host RI (SINTEF) support for effective preparation and application of the holistic test description method, such that the user group had a clear understanding of “what to test”, enabling to spend the on-site access time more effectively on “how to test”.

4 Reflection on Results of the TA Programme

To gather experiences from TA hosts, a questionnaire was sent to the hosts of selected TA, inquiring on aspects of each selected access experience. The questions posed as part of the questionnaire are given below. The answers to this questionnaire are used in the following to inform the reflections presented in this section.

Questionnaire:

1. What has the user group learned from the project?
   Guide: learnings that would have otherwise not have been obtained without the TA provisions.
2. What was the value/impact of providing access to the user group?
   Guide: direct impact on the user group's solution or research progress.
3. What was the learning for the RI host and the ERIGrid community?
   Guide: learnings that impact the development of testing procedures and facilities in the RI as well as the ability to conduct HIL, co-simulation and distributed RI experiments.
4. Where the Holistic Testing Description (HTD) has been applied, to what extent did the project demonstrate the value of the HTD and what suggestions do you have to improve it?
   Guide: was the HTD validated? Any shortcomings identified? Any recommendations for improvement?
5. Upon reflecting on the TA project conduct and outcomes, what would the RI host have done differently?
   Guide: this can include technical and non-technical aspects such as method adopted for designing the experiments or logistical planning of the user group's stay.
6. Any things that worked particularly well during the TA provision process (before, during and after the use group access) that should remain and be encouraged during ERIGrid 2.0 TA?
   Guide: this can include technical and non-technical aspects.
7. Any things that did not work particularly well during the TA provision process (before, during and after the use group access) that should be improved during ERIGrid II TA?
   Guide: this can include technical and non-technical aspects.

The following overview is divided into three parts, each with a different purpose. First, the achievements from access stays are listed in Section 4.1. That is, for a future project including a TA programme, we seek to list reasonable expectations that one can set for such a program, as seen from both visitor and host perspectives. Second, lessons learned from the host RI are listed in Section 4.2. That is, given that a RI is a part of a TA programme, the feedback which support, functionality and facilities allow for a better visitor experience, and how the RI should expect to be challenged in terms of such services. Finally, challenges are listed for defining and organising stays and potential improvements in Section 4.3. That is, given that a TA programme is part of a future project, which challenges were found for the TA process applied here, and how these challenges may be addressed in future TA programmes.

4.1 Achievements and Learnings through User Projects

Suppose you are hosting a TA program in your project, what can you expect to achieve? This section exemplifies the results obtained through the access programme both directly by user projects and indirectly, through the involvement of the hosting RI.

In general, tangible outcomes achieved by the user projects include:

- Scientific publications, preparation and completion of PhD theses
- Technical validation of industrial technology, especially through collaborations (industry/industry, and research/industry user groups)

- Maturing of academic concepts toward higher TRL (essential feedback generated through testing)
- Improvements in the service level of the hosting RIs, including opportunities for promotion of labs

Diverse other outcomes include impacts for the user groups based on the testing experience:

- Open source hardware / software validation
- Spin-off technology developments (e.g. the software validated during one TA allowed the user group to participate in an open innovation challenge; offer specific internships)
- Experimental validation of specific technology mix within top-RI offered by ERIGrid
- Validate applicability of methods, not only technologies
- Learning on verification and testing methods such as for control algorithms in CHIL
- Round of academic results with validation to complete a PhD thesis
- Extensive feedback on design choices through host RI expertise

For the hosting RI, one attractive outcome can be joint publications, both with academic and industrial partners, however, provided active involvement of RI staff in the user project, e.g., through facilitation and guidance in test design and novel adaptations of testing facilities. A hosting RI should not expect pure infrastructure provision to be considered a justification for joint publication.

If a RI is built for a certain capability, this capability is often only appreciated internally at the RI. Through TA projects, such capabilities can be matured to be used by external users for the same purpose. TA projects can also be useful to give evidence for and promote unique installation features for the specific installations. Here especially, mixed user groups involving also industrial partners are positive for promoting RI use as a test bench for the specific uses as referenced in the respective user project.

For the ERIGrid networking and research activities, a few related outcomes were noted:

- The HTD templates[3] developed in ERIGrid have been applied and proven useful in several cases, such as one with multiple RI test sites with different test configurations.
- One TA motivated models for a laboratory exercise which was later used in the frame of the educational activities of ERIGrid (NA4).
- At least one TA applied and extended concepts and methods from JRA3 on geographically distributed laboratory coupling methods.

Other valuable inputs noted by RI hosts include:

- New questions formulated by users make the host RI reconsider and extend their knowledge and lab capabilities.
- Often, the host organization has a strong interest in the field user groups and provides input, creating opportunities for joint publications.

4.2 Lessons Learned for Hosting RIs

It was noted above that among the benefits of hosting TA user projects there are learnings on the side of the hosting RI. This section reports some of the observed learnings. It is firstly referred to the technical learnings on the host RI side, then the learnings in the facilitation of user projects and collaboration aspects will be addressed.

The best learning for each RI occurs when researchers at the RI interact tightly with visitors and help facilitate the special requirements of the visitor. Some technical learnings include:

[3] Publicly available on Github *https://github.com/ERIGrid/Holistic-Test-Description* and on Zenodo *http://doi.org/10.5281/zenodo.3515048*

- Host RI staff helped to resolve the emerging challenges of the conducted CHIL experiments enabling the user to successfully complete the experiments
- RI hosts learned how to solve PHIL stability problems by using different types of solutions
- Redundancy of measurements is always recommended when it can be done
- Controller deployment infrastructure (software) needs to be available, and a mock-up interface for testing purposes should be available for the users; documentation is helpful but can be replaced by good interactions between the user group and the RI staff
- In one case, the host RI gained valuable insight in the operational procedure of wind turbines under faults; the control of an AC/DC/AC converter in a CHIL setup was also implemented at the host premises for the first time
- The user projects allowed to test the operability of the system under specific experimental conditions to spot some “weak” points of the infrastructure and re-evaluate its capabilities
- In one case, thanks to the user project, the RI host has developed a design methodology for power electronic devices based on a comprehensive testing chain
- In another case, the presented measurement methodologies and test results have improved the host facilities in terms of connectivity and additional equipment to consider
- A preliminary PHIL stability analysis before a TA visit can save lots of time in designing a working test setup. Specific guidelines to do such an analysis on paper may facilitate the process in the future.
- Multi-Site tests require extra effort for ensuring stable connections and allowing the connections in the first place

The need for coordination with the user group early on is a common observation. It helps with technical, administrative and scientific collaboration aspects. The hosting RI learned the following regarding facilitating the technical aspects of a user projects:

- A user group with clear understanding of 'what to test' will be able to spend the urgently needed access time on “how to test”
- The use of the simplified or extended version of the HTD template shall be encouraged to raise questions about the preparedness of the user:
  - the specific template use may not need to be enforced, but the questions posed by the template on test objectives, metrics and system configurations need to be answered
  - e.g., it has helped users to formulate different test setups intended to investigate
- To start defining the measurements (scenarios, methodologies, equipment, roles, expected outcomes, etc.) and involving all the stakeholders from the very beginning
- Tests flow well in cases when the user group established a daily agenda with the different steps to address, including back-up additional testing in case of early completion, or defining priorities in case of lack of time
- The user group should prepare simulation files with a specific software version and template provided by the host
- To make sure that real-time simulation or other critical hardware work is completed before the arrival of the visitors
- Users will ask for additional functionalities that may not exist initially at the outset and having the flexibility to allow that functionality will make the stay simpler
- For the host, the discussions with the user before the visit starts are needed to clarify technicalities, such that the setup can be ready for the experiments at the user’s arrival
- Close collaboration with the user group in finding solutions during the test will increase the success rate of the test
- Providing templates (e.g., simulator files) for the users before their arrival leads to optimal use of time in the lab since there are always other unforeseen challenges to cope with
- In case of physical labs, simulation models of the available RI greatly facilitate the test planning

Administrative and logistical issues are also greatly facilitated by early and frequent contact with the user group. Regarding joint publications, it was observed that specific services and collaborations are appreciated, including:

- Early involvement of the RI in definition and scoping of tests; to help the design of a proper validation and counselling towards a successful test. Validation can be a complex task – visitors may not have a clear idea of how to perform a validation. Provide that effort as a service.
- Ensure resources are set aside for direct involvement in execution of tests, development of facility in conjunction of tests and dissemination of results, setup, etc.

In terms of procedural learning for the host RI, it has been shared that adequately considering available access days vs. experiments completion time is one of the most important aspects for the success of the project. Here, experience shows that a strong involvement of the host RI can also enable ex-post completion of projects through remote RI access.

4.3 Recommended Improvements for Future TA Programmes

Based on the experience with the ERIGrid TA1 program, the RI hosts report some practical observations that may be considered relevant for future similar TA programmes.

The first set of recommendations is based on general observations from the access programme:

- Invite the user group twice:
  - Opportunities and challenges are different in each lab, especially when the experiments involve physical lab infrastructure it can be difficult to achieve mutual understanding
  - The first stay serves to see/learn about the facility, possibly to carry out preliminary tests, the second stay serves to execute experiments; in the interval, it is appropriate to prepare all materials and make a detailed experiment plan
- The TA application templates should have explicit guidelines on requiring applicants to focus on "what a test is about":
  - The users should spend more time considering what they would like to find out, and less on anticipating implementation in a specific lab
  - In the application documents, users should be asked to make explicit the motivations for the experiment (test objectives) and the required degrees of freedom
  - If the users can describe what they want to find out, and the degrees of freedom that they require, the hosting RI can more easily transfer the requirements into the lab.
- Because accounting and administrative procedures vary between labs, there should be degrees of freedom in the process from acceptance until completion of all required documents.
  - It was difficult to create a single-point-of-entry and overview of required documents, making also internal handover difficult
  - Repetition of information across documents with slightly changed templates can be a source of error; the number of documents with similar details should be minimized
  - Guidelines and internal FAQ should be available, both for the overall process and for each party in the access
  - Introducing a work-flow management approach, as a single point of control may be made available through the TA administration, automatically tracking the status of each document, listing where in the process each document is, and associated responsibilities for each party in the access procedure
- Be open to joint publications with user groups through active research collaboration already early in the TA process:
  - Good and early communication between user group and host staff is a precondition
  - TA hosting is a service not conditional on research collaboration, and thus joint publications, if desired by host and visitor should be made easy through RI host initiative

Specific observations were made based on individual user projects on several aspects, as summarised below.

On the technical preparation of users for RI visit:

- Simulation files shall be checked before the arrival of the visitors; providing simulation model templates for the visitors well in time before the experiment days leads to optimal use of resources
- Similarly, the provision of mock-up software interfaces to prepare the users controller for embedding in the lab environment can significantly speed up the deployment
- Contingency measures may be useful to discuss in the planning phase articulating alternative solutions for possible failures/malfunction related to the test setup's critical components

Coordination and collaboration between user group and Host RI staff:

- The number of visitors and stay time can be improved with thorough planning
- Better time scheduling and preparation of the user to be able to complete the whole set of the experiments
- Contact the user group more frequently in advance for better collaboration and in order to ensure that the users are well prepared and have well developed the backbone of their experiments

Effective use of the HTD method:

- More clarity of the terms and extensive examples with different setups may facilitate the productive use of the HTD template
- Effective use of the HTD can be beneficial especially for Multi-RI projects where the methodology can be helpful in clarifying the implementation plan and translating observations from one RI to another; the use of HTD should at least be encouraged, possibly become compulsory before the user’s visit as part of the RI preparation

Cross-RI knowledge sharing:

- It may be helpful to build a knowledge-sharing board or forum to exchange lessons-learned and experience in “real-time”, during the execution of the TA projects: some testing issues are more common and might have been experienced earlier and even have been solved in another RI

5 Summary and Conclusion

The TA1 WP facilitated 41 TA user projects which were diverse in terms of user groups and purpose of their RI visits. The benefits for the user groups through the access projects have been highlighted, encompassing research findings and publications, industrial technology validation and characterisation, as well as learnings on the practical use of RI and testing methodologies. The findings from TA1 user projects went beyond the scope originally defined for TA1, and motivated and included extensions of capabilities of some of the participating RI.

Perhaps equally important, the user groups engaged with the hosting RI creating an impact on the ERIGrid community of RI researchers and hosts. Apart from the benefits achieved directly for the user projects, the RI also grew in their capabilities by servicing the advanced user requests. In collaboration with the user groups an impressive number of joint publications could be achieved.

The observations from RI hosts have been summarised, both technical and organisational learnings have been highlighted. Finally, a set of recommendations for future improvement of access have been formulated based on four years of transnational access experience of the ERIGrid RI teams.

6 References

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7 Annex

7.1 List of Figures

7.2 List of Tables