Remote Laboratory Concept for Renewable Energy Education in South Africa

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Abstract

The EURYDICE project, funded by the Erasmus + program, is focusing on renewable energies to support the energy system transition to a sustainable one in South Africa and to increase the employability of the graduates of Universities of Technology. The overarching goal of the project is the improvement of the renewable energy education at Universities of Technologies in South Africa with a special focus on photovoltaics. The project wants to achieve these goals by a closer collaboration between universities and industries and the establishment and implementation of remote and mobile labs. Three Universities of Technology in South Africa and three Higher Educational Institutions in Europe work on the project. This paper presents the first results.

Keywords: Laboratory, PV System, Remote Control, Remote Access

MOTIVATION

Technical engineering education at Higher Education Institutes (HEI) is focusing on theoretical education in the classroom and practical education in the laboratory (lab). Education in energy related subjects need especially a highly sophisticated lab infrastructure to demonstrate and visualize the transformation and distribution of energy.
Not every University can afford such an expensive infrastructure.
It can also be said that the movement to Industry 4.0 can be translated into a teaching 4.0 protocol, this could include remote labs that incorporate IOT etc.
For the students, a real world test shows the deviations between pure theoretical calculations and real world measurements better than simulations, because they get an impression on dimensions, sounds e.g. of motors and background information as necessary mechanical installation technologies.
Within the EURYDICE project, an infrastructure was developed where Universities can share their energy experiments due to mobile labs and due to remote accessible infrastructure. A remote lab will be installed and implemented at each of the three South African Universities. The paper will present the remote method and a lab for off-grid and micro-grid PV systems.

LABORATORY INFRASTRUCTURE

PV Micro-Grid System

The lab contains a micro-grid system, which is powered by a combination of solar, wind and battery power. Figure 1 shows the basic system layout with the following specifications: 5 kW stand-alone inverter; 1.3 kW Solar PV grid-tie inverter; 1.0 kW Wind turbine with grid-tie inverter; 1.8 kW Solar PV battery charging system; 24 V / 200 Ah GEL battery storage.
The shown infrastructure can be used in education to show different system configurations and the impact of each component to the overall system performance. The students can analyse, control the power flow within the system, and analyse different system configurations for different applications or locations etc.

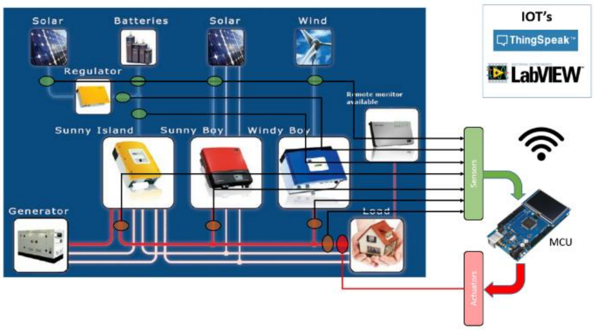

Figure 1: Infrastructure of the PV micro-grid system

PV Mobile Lab System

The mobile lab is a challenging prospect as all components will have to be installed in a cross-terrain trailer/unit. The trailer comes along with basic specifications. Integration between the existing trailer systems and proposed renewable power sources must be accomplished and IoT devices must be monitored and reported to the on-board PC with a LabView platform. Figure 2 illustrates the concept with the proposed system ratings.

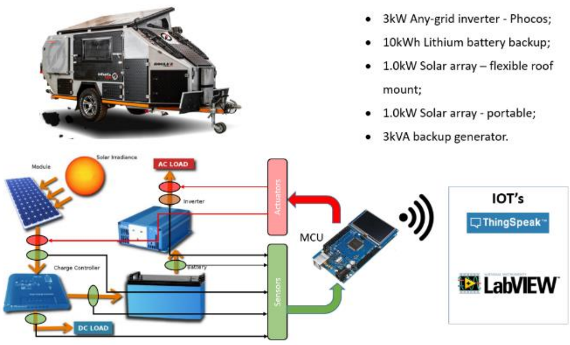

Figure 2: Infrastructure of the PV mobile lab system

REMOTE ACCCESS

Use Cases for a Remote Lab

The concept of a Remote Lab can be seen in Figure 3. The technical experiment equipment or test bed consists of its controller and Human-Machine Interface (HMI). A remote twin is made of the HMI that can control the test bed via the internet the same way as the on-site HMI, if control is handed over to the remote HMI twin.

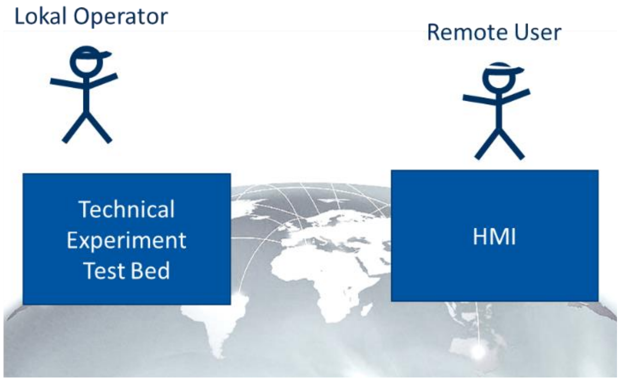

Figure 3: Remote Lab Operation

There are several Use Cases for the local operator of the remote lab, the technical expert for the test bed and on the remote side for the student or researcher using the infrastructure remotely.

Use cases for the operator or researcher at the university following use cases can be identified:

- Remote control of offsite long-term tests
- Remote control of field tests (same as industrial applications)
- Easy to supervise the experiment
- Keeping experiment in a safe operation with software and firmware limits.
- Large class of students can be handled
- Flexibility of controllable access rights that can include flexible access rights (read only, control)

Students use cases are:

- Lab exercise with fully remote control on HMI but a HMI remote twin
- Preparation of face-to-face Lab experiment on physical equipment
- Post processing of data
- Safety of remote-control twin such as that of dangerous experiments. (Remote twin for industrial applications such as remote control of wastewater pipes, disassembling of nuclear reactors, signal disruptor, underground machining)
- Distant education that could include case of high travel costs, illness or pandemics
- Automated report generation of experiment values via e-mail
- ^Exercises with flexible timeframe

Safety and Security Concept

Safety concept on-site. Accessing and especially controlling an energy system remotely is in general a safety critical topic. On-site experiments need either an intensive safety education and test for researchers and a safety responsible person, which is in general the lab engineer, when students doing experiments on-site in the lab.

Safety concept remote. As a minimum, the same safety level should be achieved when using the infrastructure remotely. Therefore, safety requirements must be defined and implemented into the remote control. It must be ensured that the experiment only runs in a safe operation area. The operator should be able to switch on and off the experiment at any time. The access to the experiment must be in a legal way concerning the university security system.

Safety requirements for remote operation:

- The remote user must identify him or herself
- The remote system should be able to distribute and withdraw access rights between all remote user
- The remote access should not create an unsecure portal on the university access system
- The operator defines safety limits, within the remote user can control the system
- The remote user cannot exceed safety or test bed limits and hardware limits must be hardcoded in firmware.

Implementation

To match the listed requirements, a solution was implemented where centre accessed cloud data storage is used to exchange measured values from the test bed as well as the control values from the remote user. Figure 4 shows the implementation using Google sheets, for this solution and for data exchange based on the remote control of a motor – generator test bed as a starting point for the PV exercises.

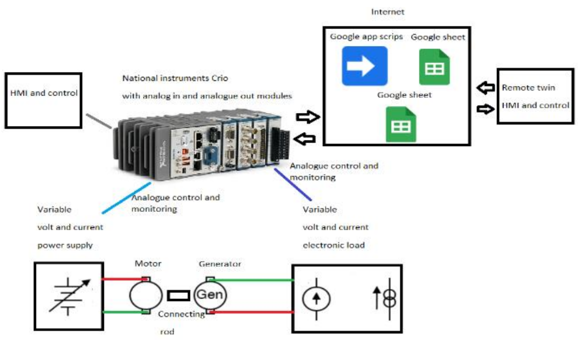

Figure 4: Remote Lab Implementation motor test bed

The motor-generator test bed consists of a controllable power source controlling the motor, and a controllable power load setting a load on the generator side. These devices are controlled via the cRIO with custom control firmware and the HMI.
Thus, this local automation hardware, consists of flexible analogue and digital IO systems with a built/in controller and measures the system states with sensors. The local HMI shows measured values and is able to set control signals to the system's hardware peripherals. In this case these are the controllable source and load.
The local automation hardware uses the local internet to get access to the Google sheet and writes values in the sheet's cells via URL GET commands and corresponding written and published google cloud scripts.
The URL with values updates a google sheet.
The remote user gets an executable file of the remote twin HMI with a similar cloud connection to the google sheet commands programmed in (via written and published) google cloud scripts. When the remote HMI executable is run on a remote system, the user is asked to identify him- or herself for access control and level to the hardware. After successful identification, the remote HMI reads cells from the Google sheet and shows the measured values of the real system in the lab. If the remote user wants to make changes control input settings to the real system in the lab, then the control inputs are set as it would on the onsite HMI. These are written into the cloud Google sheet, then read by the local automation hardware and subsequently controlling the onsite system.
The delay time of the communication between the online control was measured as approx. 2 seconds, which is appropriate for many systems.
If the experiment needs faster reaction times one can add a feature in which a test set is send, then the local automation hardware can take measures at higher measuring rates and transmit the test results corresponding to the test set afterwards for remote analysis.

The micro-grid lab remote access is shown in Figure 5. The user gets information about the single values such as PV voltage or PV current. Based on the experimental level, the remote HMI can provide calculated information like PV power. The remote user can switch loads or additional auxiliary energy sources on and off, he can analyse recorded values and make calculations on e.g. state of charge of the battery, power losses within the system.

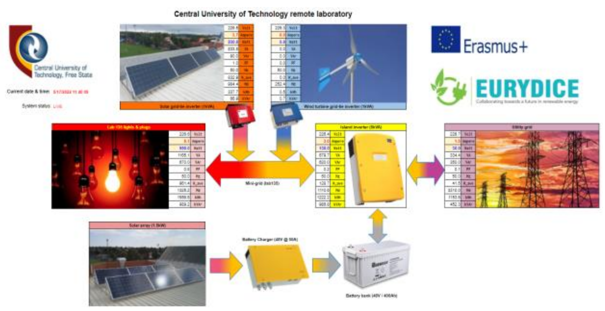

Figure 5: Remote Lab Implementation micro grid lab

CONCLUSION

The purpose of the paper is to show how a remote access to energy related labs can be established on a safe and easy way. The solution shows an easy and safe way to get remote access to laboratory infrastructure at a different location. A first trial use was done to identify some minor problems.

In the beginning, the focus is on the observability. As a next step the project moves on to the controllability of the system. In systems with higher complexity, the operator has to think about all possible combinations the remote user can do and limit or exclude critical combinations.

The paper shows that remote laboratory infrastructure in PV energy systems is an alternative for onsite laboratory and can enable students and researcher to get access to infrastructures at other locations.

ACKNOWLEDGEMENTS

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