Brussels, 30 November 2020 (remote)

A Lab demo as taught in TEACHY

Massimo Santarelli, Politecnico di Torino (POLITO)

Task 3.1 – Development of 'remote lab' concept

SOFC/SOEC cells or short stack (1-3 cells) characterization

A test station for the analysis of circular and squared planar SOFC/SOEC with capability to characterize different sizes cells (up to 11x11 cm²) and provide gaseous and liquid feeds. The rig is equipped with an electronic load and an impedance analyzer. On-line gas analysis is provided.

Sealed test-fixture for single cells

Task 3.1 – Development of 'remote lab' concept

SOFC/SOEC single cells or short stack (1-3 cells) characterization

A test station for SOFC/SOEC testing with capability to provide gaseous/steam feeds to cell/short stack and equipped with an electronic load for cell characterization has been interfaced with the web for remote tests controls.
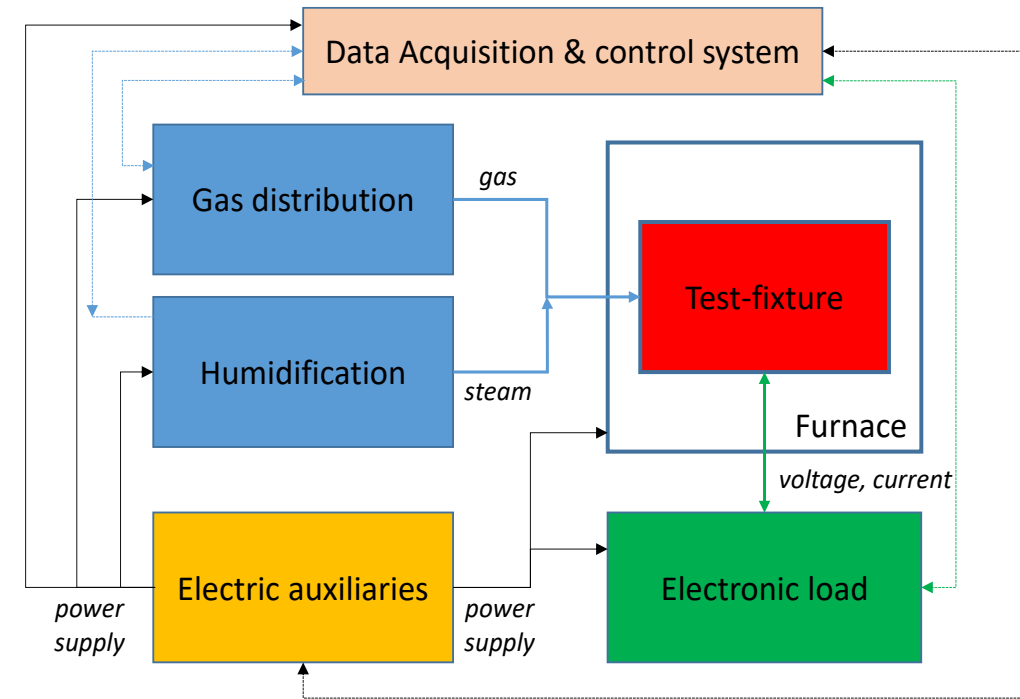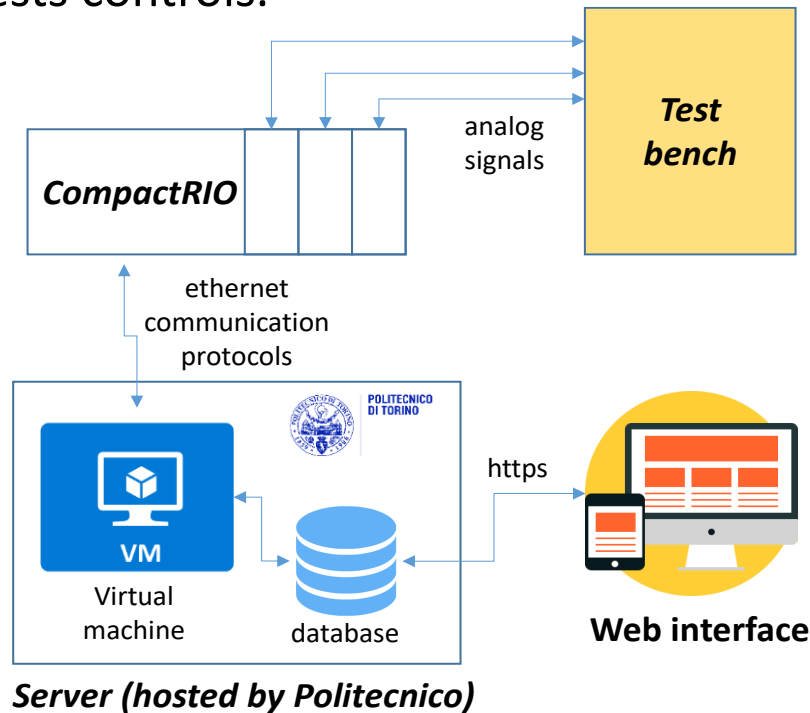
Test-rig (right) and remote control system (left) schematic

Progress: Status and Achievements

Task 3.1 – Development of 'remote lab' concept

- Renovation of experimental apparatus hardware/software
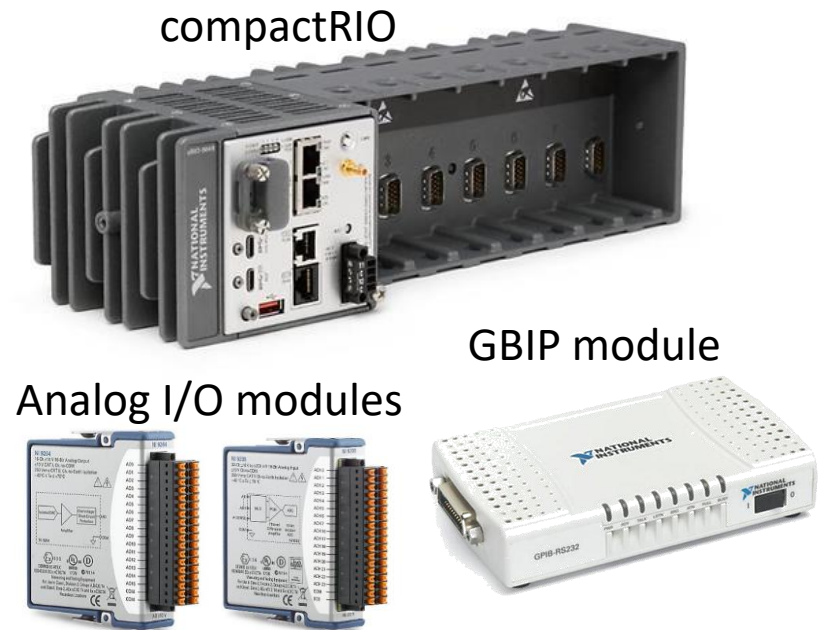
Progress: Status and Achievements

Task 3.1 – Development of 'remote lab' concept

- ### Experimental apparatus hardware/software

A local PLC (compactRIO, NI) receives the input/output analog signals from/to the test rig through NI modules connected to MFCs (0-5 mV signals) and electronic load (GPIB connection).

The PLC software communicates by Ethernet protocols to a virtual machine - hosted in POLITO servers - where the control software is installed.
A database (also hosted in POLITO servers) stores all the test-rig data in input/output.

compactRIO

GBIP module

Analog I/O modules
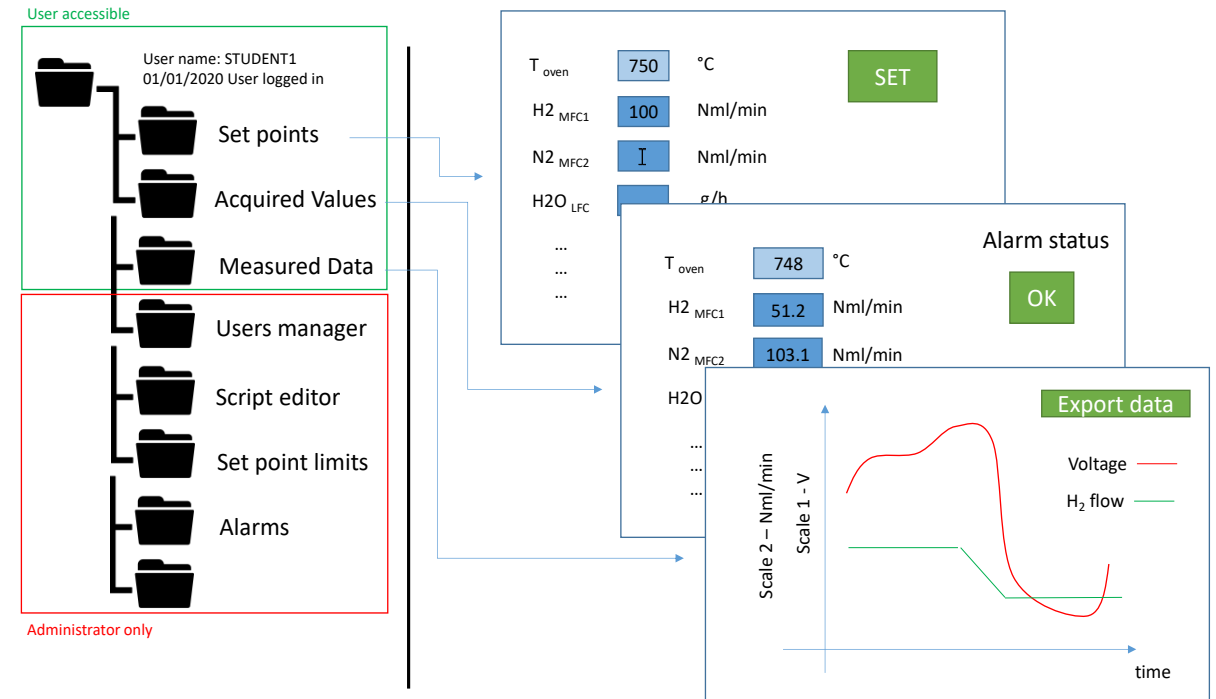
Progress: Status and Achievements
Task 3.1 – Development of 'remote lab' concept

- Remotisation of the test rig

The architecture of the control software has been designed, defining all the variables to be acquired and modified and the control actions to be implemented.

The web user interface will be accessible by PC and smartphones.

Different levels of access have been defined with administrator/user levels, that will allow to control the remote access to the test-rig and to safely operate experiments within safe ranges of the controlled variables.

Progress: Status and Achievements

Task 3.1 – Development of 'remote lab' concept

- Remotisation of the test rig

The remote control software interface has been developed, implementing all the levels of interactions of users with the variables to be acquired/modified on the test-rig (PLC interface) through the virtual machine in POLITO servers. The control interface will be accessible by web anywhere in the world. First beta version release on 27/03/2020.

Structure of web control interface:

- **Experiment management**: administrator level, setup of experiment profiles for group of users

- **Variables management**: administrator level, settings of variables

- **Users Manager**: users (students, other) access managed by administrators (POLITO staff)

- **Graphs and data**: data acquisition, accessible both to admin. and users (users with limitations)

- **Logs, alarms and message**: communications to administrators through POLITO mail system

Progress: Status and Achievements

Task 3.1 – Development of 'remote lab' concept

- Details on remote control architecture

- **Experiment management:** Admins. can create experiment profiles, in which a limited number of variables with restricted range is assigned to each profile. Profiles are generated to be associated to Users (eg. students)

- **Variables management:** management of variables by Admins.; assigned all information to the variables processed in the control system (cRIO address, type: read/write, unit of measure, range, etc.)

- **Users Manager**: levels of control
    - *Root user*: super-user that assigns Administrators access to control system
    - *Administrators* (POLITO staff): full test-rig control and full management of Users
    - *Users* (students or external staff): limited test-rig control in assigned dates and hours, divided in groups (eg. classes) and assigned to predefined experiment profiles (by Administrators)

- **Graphs and data:** access to data visualization/download only for experiment profile variables (for Users) during valid access time. Administrators have unlimited access.

Progress: Status and Achievements

Task 3.1 – Development of 'remote lab' concept

- Renovation of experimental apparatus hardware/software
  - new mass flow controllers (MFCs) → acquisition done
  - new sealed housing for solid oxide cells (SOCs) → acquisition done
  - new data acquisition system (PLC) → acquisition done
  - test-rig rewiring, new PLC connection, safety assessment (ATEX) → acquisition done
  - local software implementation on PLC → acquisition done
- Remotisation of the test rig
  - Remote control interface → under finalization
- To be finalised (some delays are due to covid-19 limiting our activities in the lab)
  - Finalization (test bench ready in the lab and connected to the web) foreseen in January 2021
  - Test of the web interface in February 2021
  - Remote test bench available for use from March 2021