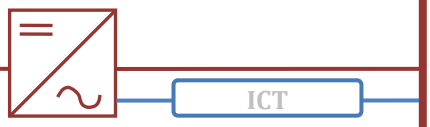
Hes·so VALAIS WALLIS
School of Engineering

GridLab



GRIDLAB HEI-VS

Laboratory for Integration of Renewable Energy and Storage to the LV distribution Grid

GridLab Low Voltage

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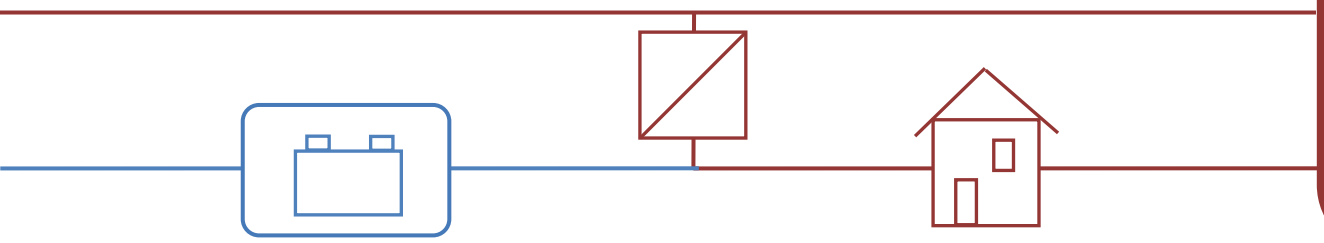

1 INTRODUCTION

The GridLab Low Voltage is a full scale experimentation platform dedicated to research and teaching activities in the field of renewable energy sources and storage integration into the grid. A three phase 400Vac feeder to which loads and sources are connected is at the heart of the GridLab LV. For better efficiency and increased flexibility, consumer's loads, production plants and storage systems are emulated with the help of static converters. A state to the art communication system allows data exchange between converters and a centralised control unit. Real loads, storage units and a photovoltaic production plant complete the GridLab LV for components testing and evaluation

Figure 1: Panoramic view of the GridLab Infrastructure at HEI-VS

The GridLab LV infrastructure is located at HEI-VS in Sion, a branch of the University of Applied Science, Western Switzerland (HES_SO). It will be fully functional by the End of 2014. Partners within the HES-SO involved in the design of the platform rely on a long practical experience in Power electronics, control techniques, LV distribution grids, Electromagnetic compatibility and ICT.

2 OBJECTIVES

The functionalities of future Smart Grids need to be investigated in the frame of our research activities. Future engineers must acquire a sound understanding of them through practical work executed during their schooling. Grid monitoring, grid control, persons and equipment protection, Power Quality, distance control of production and consummation, Energy Demand Side Management ,island operation, EMC, grid start-up, all find supporting tools for investigation or practical training at the GridLab HEI-VS Low Voltage platform.
The GridLab Low Voltage is designed for:

- educational activities
- applied research and development
- industrial component testing and evaluation
- demonstration purposes

Research or educational activities can apply to component level or to the power system levels.

The GridLab Low Voltage is a show case for the state to art Smart Grid technologies in term of energy conversion, communication and control within the low voltage distribution systems. In further development steps, the GridLab LV will be able to run for a limited time in islanded mode, without any connection to the national grid. A DC distribution bus section will soon be added to the platform as well.

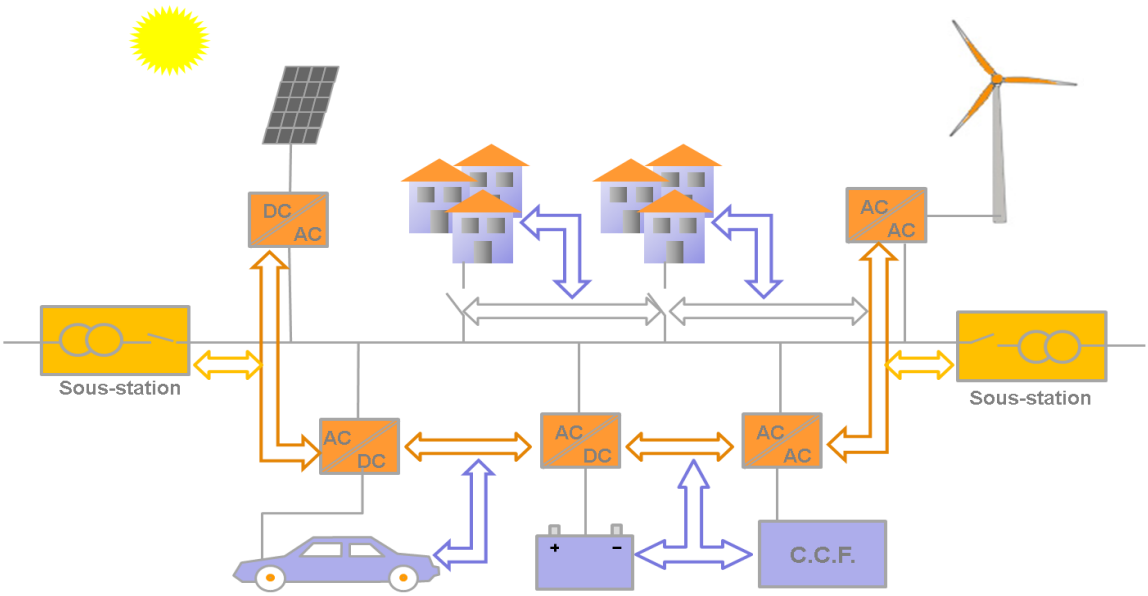

Figure 2: Electrical distribution and communication systems in GridLab Low Voltage

The figure hereafter illustrates one GridLab LV District unit in one of its application: the emulation of a district line with three distributed energy producers along the line. Each house is emulated by a 4Q converter. Active and reactive power of the three houses on the right can be distance programmed. In a typical scenario, reactive power absorbed by the 'pro-sumers', will keep the line voltages within the limit accepted by the local grid code. The line voltage variations measured by smart meters and power setting values are transmitted to the district control unit through IEC 61850 based communication protocol. Optimal control strategies can be implemented and evaluated at the level of the control unit.

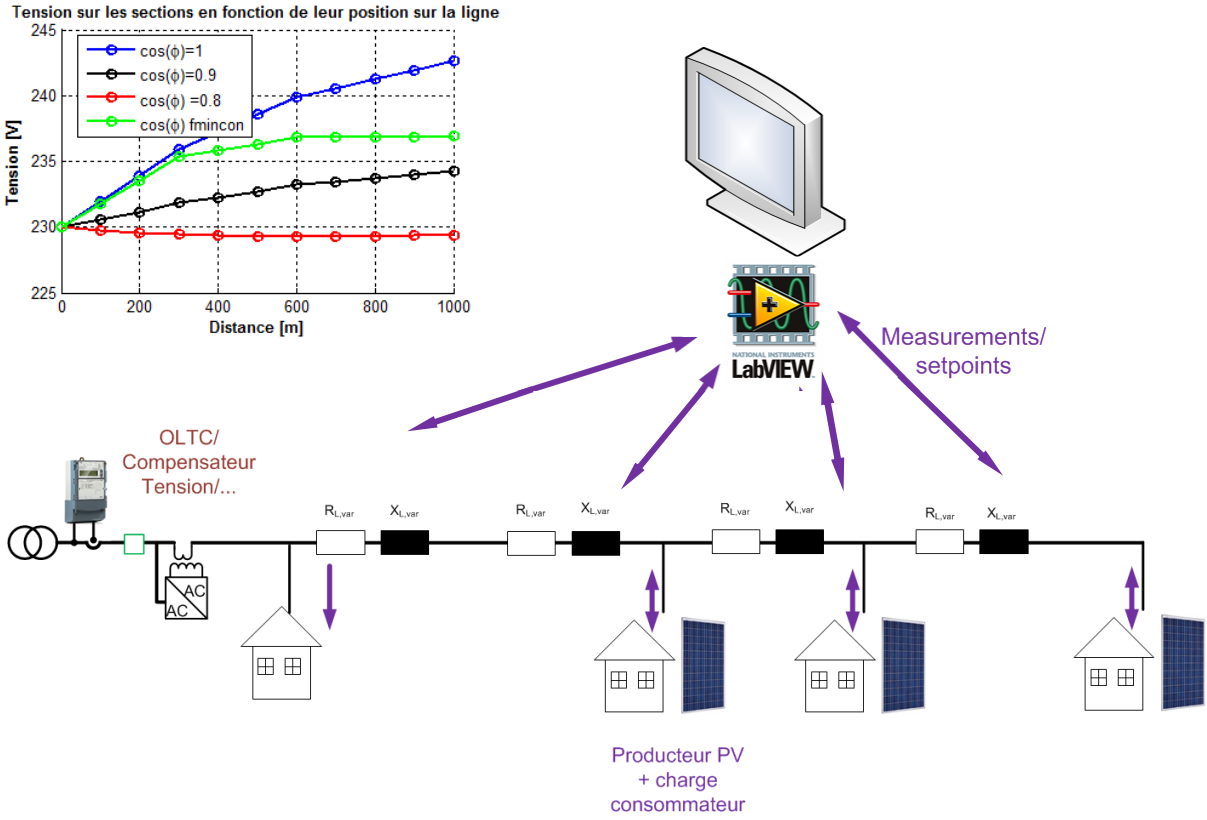

Figure 3: Control of the 3 x 15kW district Unit for a grid control strategy scenario

3 REALISATION

Energy transfers with the GridLab Low voltage feeder are very efficiently controlled through bi-directional static converters. The 3 x 15 kW units equipped with industrial Active Front End were developed in collaboration with ABB Drives. Up to twelve 15kW AC/AC converters can be parallel connected by one side to the GridLab Feeder and by the other end to an independent section of the 400VAC Grid. This solution allows a reduced overall energy consumption of the laboratory, while providing great flexibility of use.

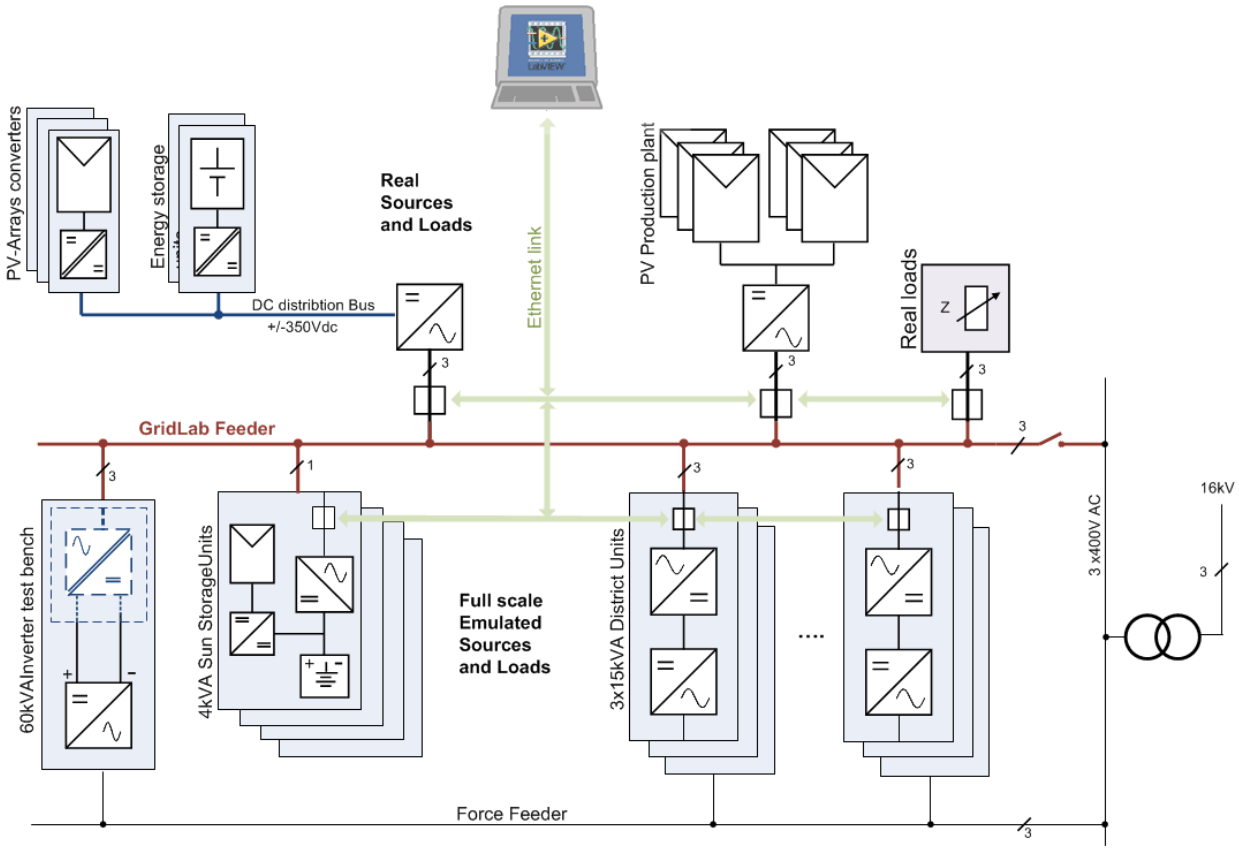

Figure 4: Simplified block diagram of GridLab Low Voltage infrastructure

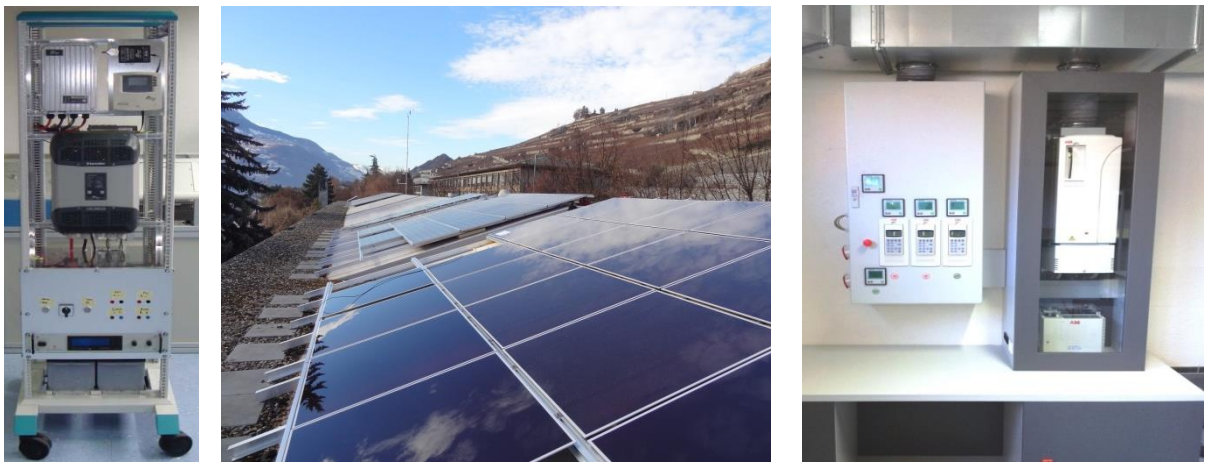

Figure 5: Single phase Sun Storage Unit (left), PV power plant and 3-phase district unit

Four additional battery converters with lower power ratings and single phase connection to GridLab Feeder allow emulation and investigation of small scale Sun-storage systems.
Real' energy sources and charges can be connected to the GridLab feeder: a 5kW photovoltaïc plant with respective PV inverter is located on the roof directly over the GridLab; different storage unit with total capacity of ca. 20kWh will also be available.

For reasons of economy and in order to provide a more realistic environment, the platform consists of industrial components from the market. In order to meet the needs of various research projects, it is planned to install a dozen 3-phase sources/loads with a total capacity of approximately 200kVA, a dozen single-phase source/loads (30kVA) and some storage units. Bidirectional laboratory DC voltage sources allow testing of Active In-feed Inverters developed at the institute or by partner companies. The low voltage network linking all laboratory equipment will be modelled by passive components (R and L) or by segments of standard cables.

4 ICT AND IEC 61850

Energy transfers between producers, consumers and storage systems are measured in real time by individual power meters and power data is systematically available for all other equipment through the WLAN Ethernet connection.
At first native communication systems are used to address GridLab equipment's. In a second step, communication and data exchange between all equipment will be realised directly through Ethernet, according to the IEC61850-90-7 standard: Object models for power converters in distributed energy resources (DER) systems. Inverters with native IEC 61850 interface are under development.

For the GridLab to be representative of a low voltage network with monitoring, Smart Meters will be implemented at specific points of coupling. High End Smart Meters will be used, allowing monitoring of the Power quality.
Data exchange through Mains Communication Systems can be implemented as well, for instance between Smart Meters and the central control unit. Additionally to communication and control technology, the Electromagnetic interferences between MCS and the harmonics generated by the inverters can be measured and investigated in a systemic approach.

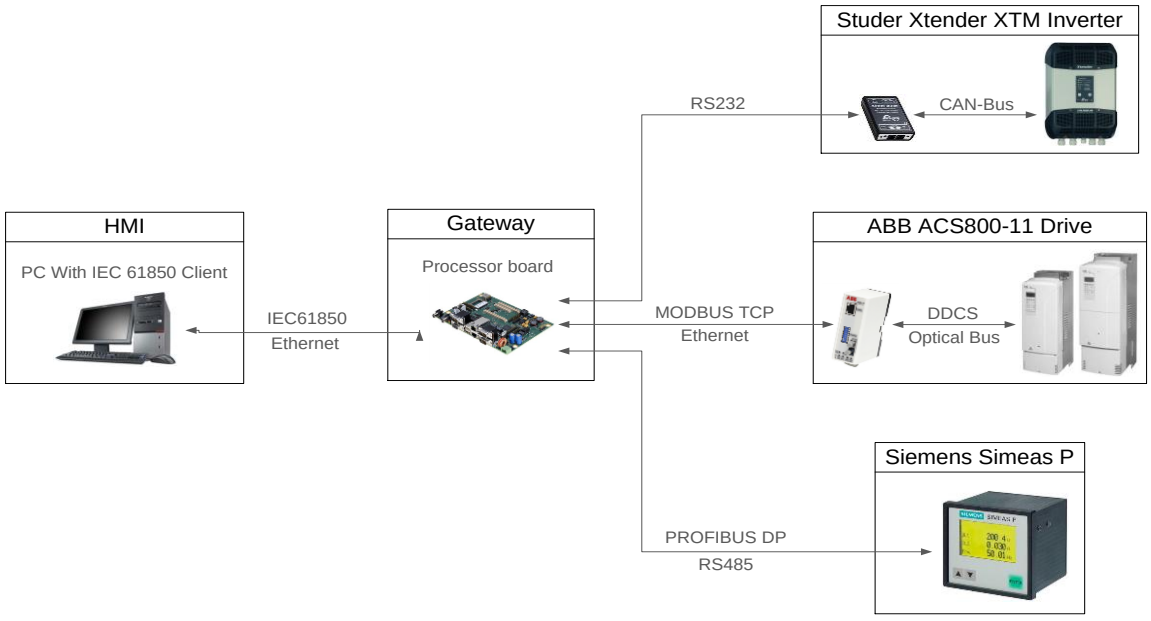

Figure 6: ICT infrastructure for the GridLab Low Voltage

5 EMC TESTING

The infrastructure of the GridLab LV offers an interesting tool for the evaluation of the impact of distributed energy production on a low voltage line feeder in term of Electromagnetic compatibility (EMC).

5.1 EMC at the Point of Common Coupling in the district unit

The district unit allow measuring the harmonic currents generated by Active Infeed Converters, as well as the harmonic voltage resulting at the PCC. Variation of the harmonic impact can be observed with one, two or three similar inverters located at different distances from the PCC and working at adjustable power. Current exchanges and voltage between two inverters can also be measured on one intermediate section of the feeder.

It is also possible to insert a LISN (Standardised line Impedance Network) or a specific line between the PCC and the GridLab low voltage feeder. In the case of the District Unit, pro-sumers are emulated with industrial converters, with specific harmonic rejection in the low frequency range (250Hz..2.5kHz). The switching frequency and EMC-filter cutting frequency are lower than for a state of the art PV inverters. Lines and cable are emulated with inductance and resistance. A section of real cable can be inserted for a more real and accurate frequency response is needed.

5.2 EMC testing for Active Infeed Inverters

A test bench for individual equipment is also available at the GridLab facility. Beside fonctionnal testing, the test bench allows high accuracy converter efficiency and EMC measurement, on both DC and AC sides. Tests can be conducted up to 66kW with programmable laboratory power sources and input DC voltage between 100 and 1200VDC. Direct feeding from PV panels located on the roof of the laboratory is also possible.

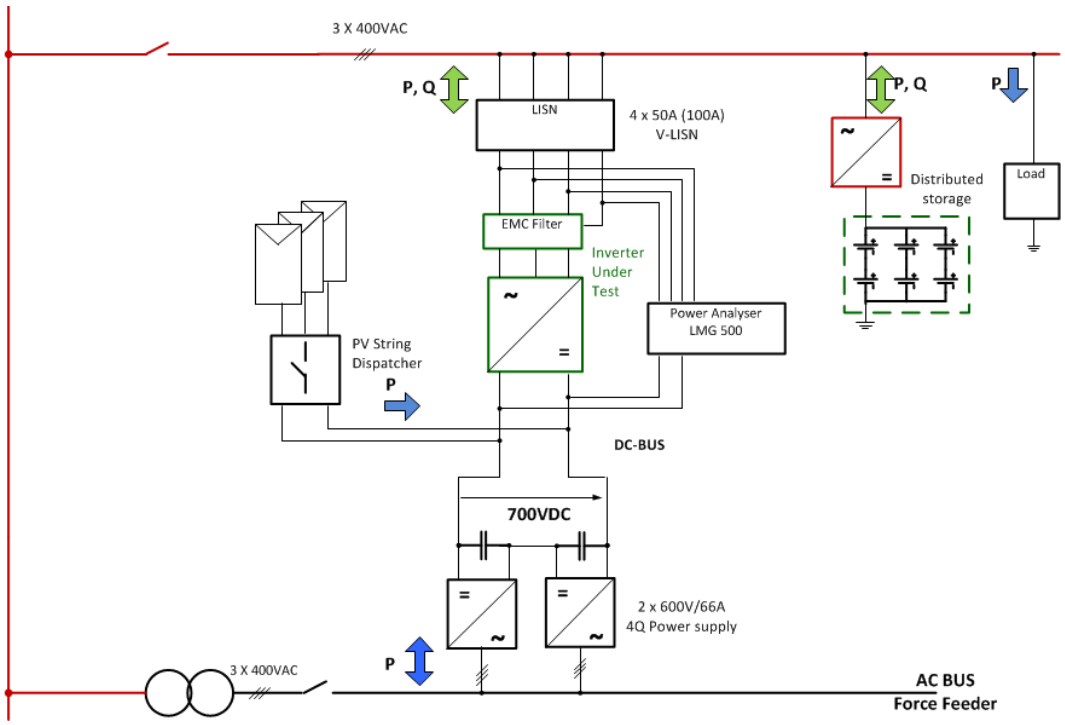

Figure 8: Test bench for individual Active In-feed converter

Available equipemnt for EMC testing:

Line Impedance Stabilisation Networks are available for DC and for AC side:

- 16A 4 line V-LISN (CISPR 16 , 9 kHz – 30MHz)
- 50A 4 line V-LISN
- 100A Dual Line V-Y-Δ LISN for GCPC

Measuring equipment's include:

- Power Analyser : Zimmer LMG 500
- Portable Power Analyser : Fluke 435 ii
- Spectral analyser : SRS SR1 (0 to 200kHz)
- Spectral analyser : Advantest R3192 (9kHz to 3Ghz)
- 12-bits resolution digital Oscilloscope : Lecroy WaveRunner 604zi
- high accuracy current and voltage probes

6 GRIDLAB LV LOADS AND SOURCES WITH POWER RATINGS

	Equipments	Power
District units	4 x 3 bi-directional industrial converters (ABB ACS 800)	12 x 15 kVA
Sun Storage units	Battery converters +PV + batteries (Xtender + Variotrack)	4 x 3,5 kW
Storage	Batteries (electrochemical) Batteries (electrochemical)	8 x 12V/150Ah 8 x 24V/100Ah
PV plant	Monocristalline Thin Film (Oerlikon) Thin Film (Inventux)	3 x 265W 6 x 110W 24 x 125W
Converters	DC/DC converters 1-phase PV inverters 3-phase PV inverter	4 x 125W + 1x 750W 3 x 3kW 1 x 10kW
Lab-sources	AC/DC 1Q AC/DC 2Q DC/DC 2Q	4 x 3kW 2 x 32kW 0…1200VDC 1x 10kW
LISN	4 x 50A AC V LISN 1 x 100A DC LISN	

Table 1: Main equipment of the GridLab Low Voltage with power ratings