Interreg
EUROPEAN UNION
2 Seas Mers Zeeën
INCASE
European Regional Development Fund

D2.1.2 Large scale PROFIenergy pilots for preindustrial application:
KU Leuven set-up

ondernemen in west-vlaanderen

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The INCASE project

Industry 4.0 (I4.0) is the next industrial revolution. Manufacturers are focusing on client-specific production and added-value products. In Germany 84% of the companies feel the pressure to digitize and 57% will significantly change their business model due to the digital revolution. Germany is world leader in this revolution. The project main objective is to ***close the gap between the 2 Seas region and Germany & other leading countries***, by developing and demonstrating the necessary key technologies towards companies, in this way facilitating the conversion towards I4.0.

INCASE develops knowledge, innovative applications and pilots on key enabling automation technologies for the future I4.0. INCASE will deliver ***10 thematic demonstration trajectories*** on those key enabling automation technologies for smart factories and green technologies for smart homes and factories. The demonstration actions will inspire practicing engineers towards new products and new production methodologies. The intermediary organizations will actively create awareness on the future I4.0.

The project contains ***three main work packages***. ***WP1*** develops pilots on key enabling automation technologies for Industry 4.0, to achieve an early market uptake by and increased awareness of the manufacturing industries. Involved technologies are Industrial Communication (PROFINET, Power Line Communication, Proficloud, Networked Control) and Integrated Design (Mobile robotics, Industrial Hardware Targets, Cosimulation). ***WP2*** develops pilots to reduce energy consumption in both home automation and industrial automation, and increase the awareness & knowledge for the automation and manufacturing industries. Involved technologies are Communication and HMI technologies for smart factories and smart houses (PROFIenergy, Power Line Communication for smartgrids, Control & HMI for Smart Houses, energy monitoring devices connected to the Internet of Things). ***WP3*** develops demonstration tools, based on the pilots, to perform numerous demonstration actions for practicing engineers in industry. In this way the knowledge on new technologies is increased and an early market uptake of Industry 4.0’s new automation technologies is achieved in the 2 Seas region.

The ***main objective*** of INCASE is preparing the industry (automation & manufacturing industry) for the future “Industry 4.0” (I4.0) and “Industrial Internet of Things” (IIoT). This is done by:

- Creating awareness of technical management and decision makers of companies on the possibilities of the new technologies.
- Preparing practicing engineers by demonstrating new technologies for the future smart interconnected factories, smart buildings and sustainable engineering.

The project ***specific objectives*** are:

- Pilots on Proficloud
- Pilots on Stress-testing on PROFINET
- Feasibility study on PLC
- Pilots on Networked Control
- Pilots on Integrated Design
- Pilots for PROFIenergy
- Pilots for smartgrids using PLC
- Pilots for Control&HMI for Smart homes
- Pilots for energy monitoring devices connected to IOT, IIOT and industrial networks
- Demonstration tools & actions

This project has received funding from the Interreg 2 Seas programme 2014-2020 co-funded by the European Regional Development Fund under subsidy contract No 2S01-049.

1 Introduction

The large PROFIenergy demonstrator of KU Leuven is a levitation setup. The goal of the levitation setup is to control the height of a beach ball, using a ventilator to change the airflow used for the actual levitation (Figure 1). In this simulated production process, hot air is produced with a heating resistor (180 Ohm); this heating resistor can be turned off during the production pause. In order to have a base load an additional resistor of 680 Ohm is added; this base resistor can logically not be turned off during the demo.

The purpose of this setup is:

- To demonstrate the energy savings and benefits of a PROFIenergy implementation in a larger setup, using industrial components.
- To do accurate energy and power measurements of the individual components; these are use in the calculation tool (D2.1.3). All components are in the 3 use cases provided by observer partner Volvo Cars Gent.
- To check the behavior of network components and diagnostic tools when PE mode (or complete turn off) is used.

To show the energy savings different demo modes must be implemented to get a proper comparison of the energy savings. The production cycle with two types of pauses are shown in Figure 2 a and b.

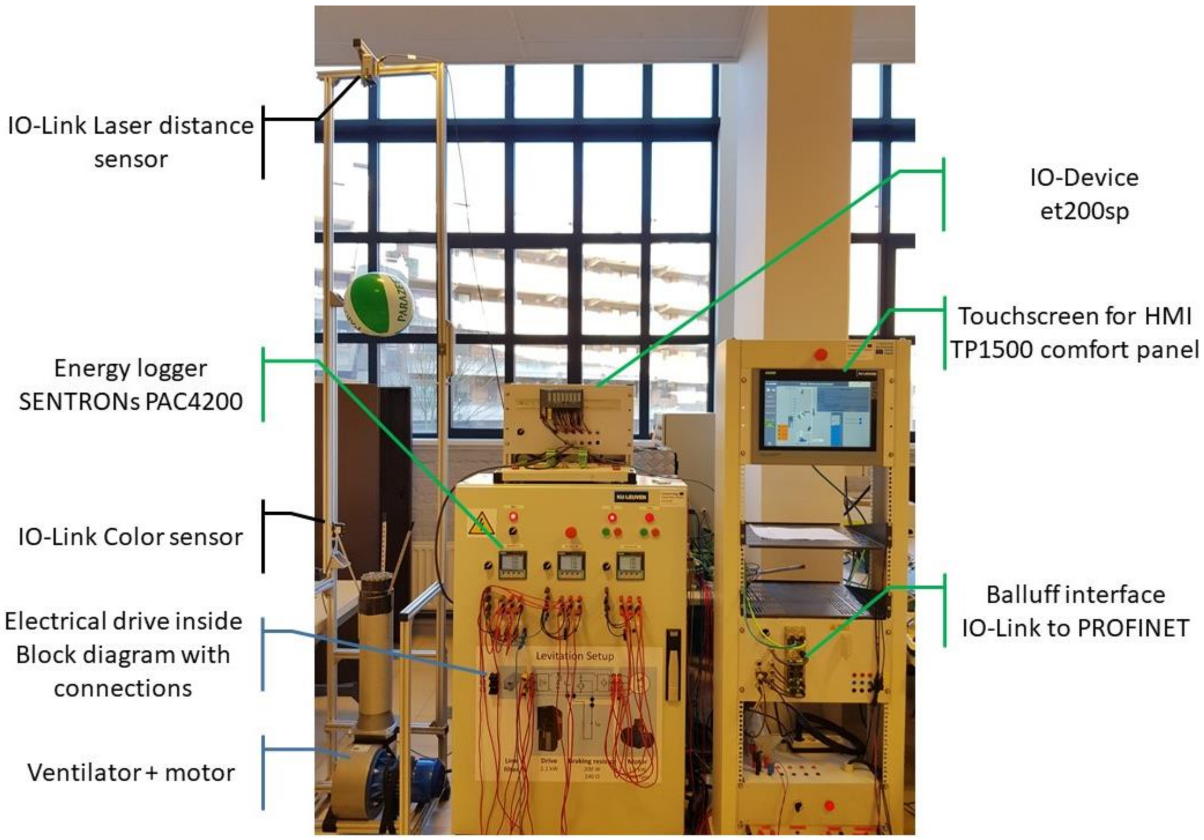
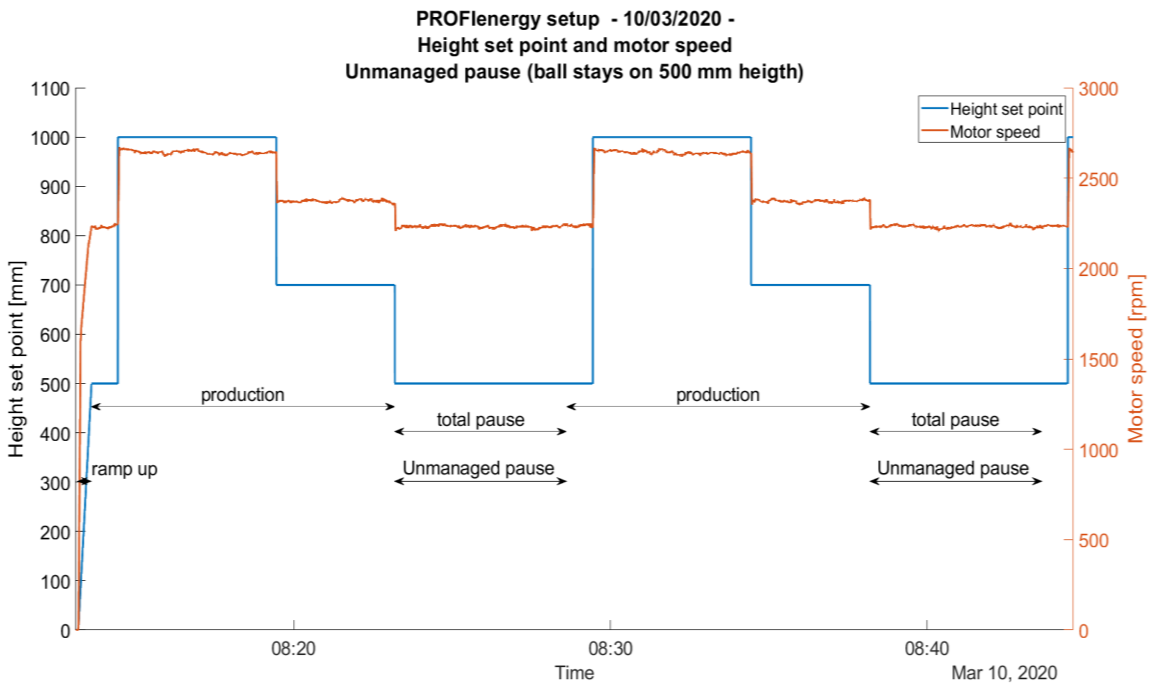
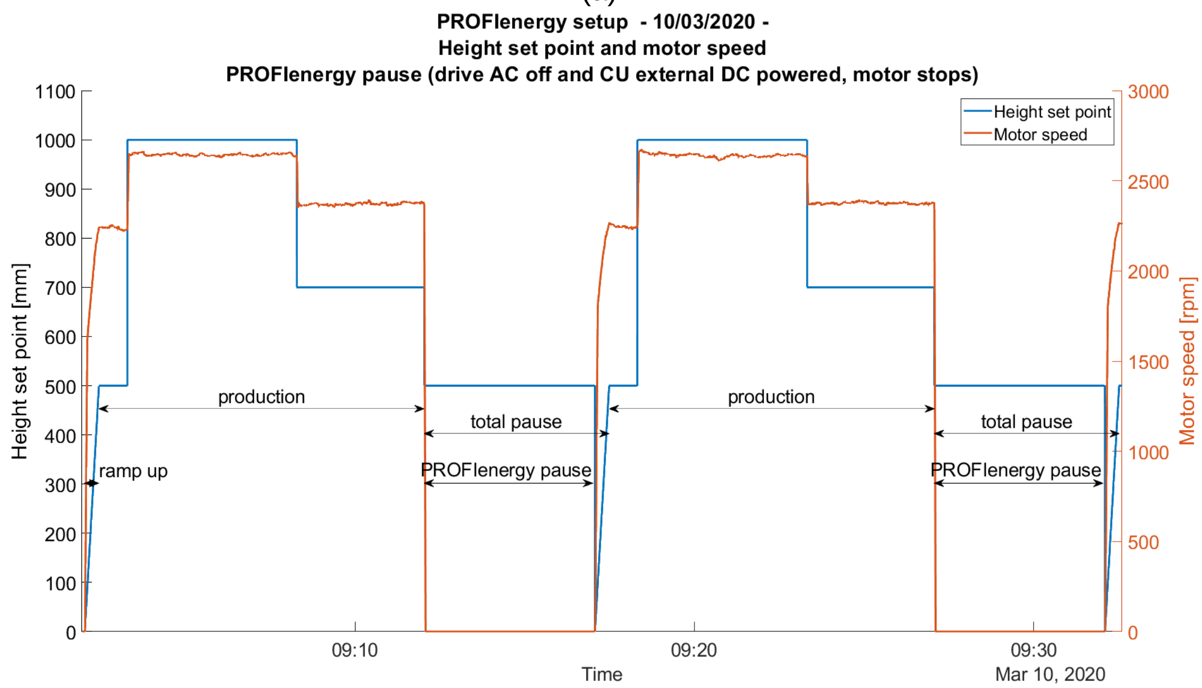


Figure 1: Levitation setup – green are PROFINET components, black are IO-Link components, blue indicates information..



(a)



(b)

Figure 2: Demonstrator modes PROFIenergy and Unmanaged pause. (a) Unmanaged pause height set point and motor speed. (b) PROFIenergy pause height set point and motor speed.

2 Development of the levitation setup

2.1 Brief hardware description

The schematic overview can be found in Figure 3. The measurement points (indicated with circles) are measurement points on the enclosure door for voltage and current. Refer to Figure 4 for a typical connection during measurements. The numbers at the end of PROFINET component names are the last part of the PROFINET addresses.

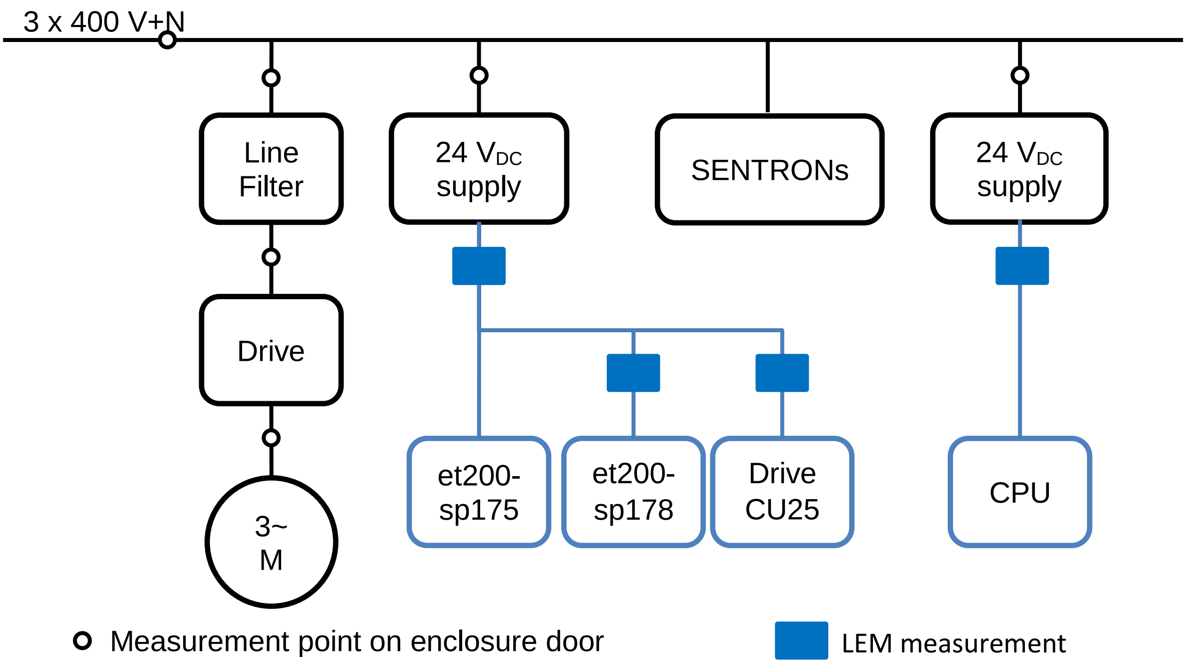


Figure 3: Schematic overview of the measurement points in the electric circuit.

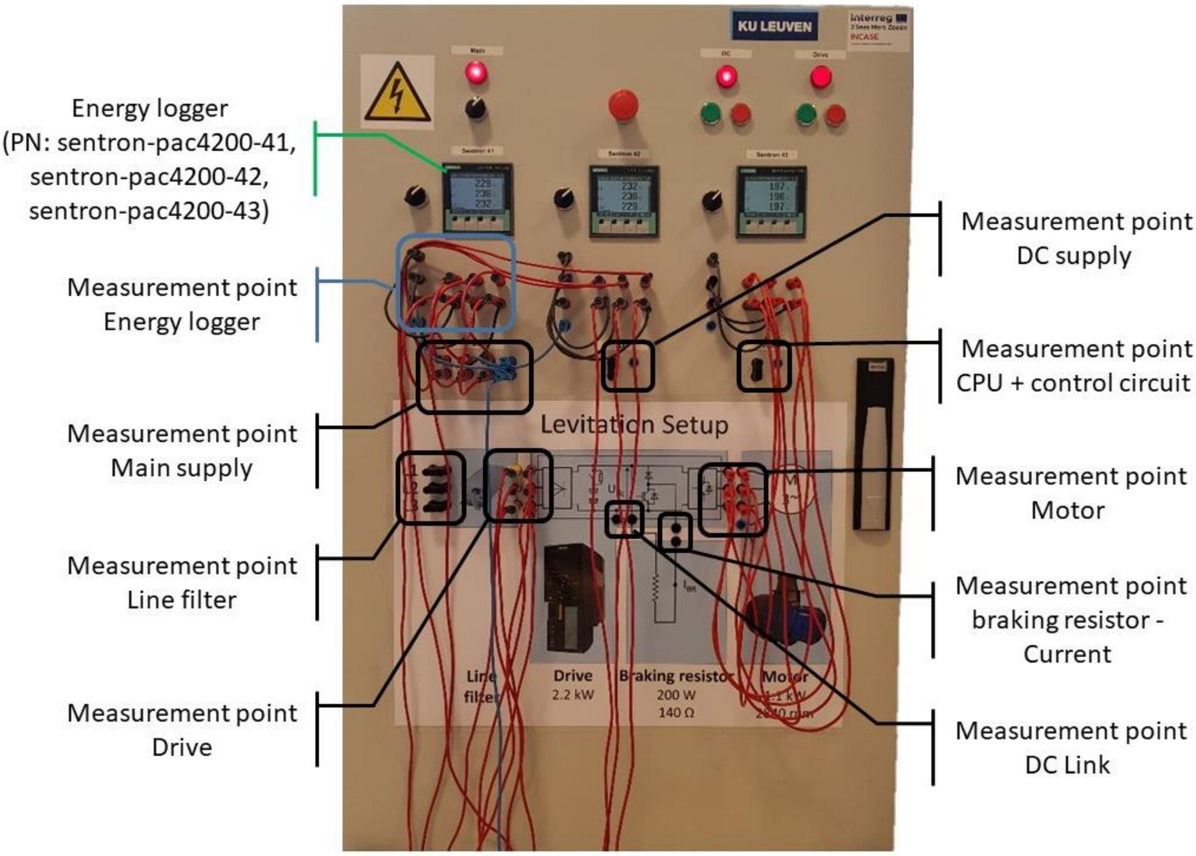


Figure 4: Door layout with at the top the SENTRONs and at the bottom the block diagram of the drive.

With the three SENTRONs mounted on the door (Figure 4, Figure 5) it is easy to measure on different points of the setup. Inside the enclosure are four LEM boards (Figure 6) which measure DC currents. These LEM boards are also equipped with a voltage divider. The LEM boards are connected with the et200sp178 which converts the input voltages into the corresponding voltage and current measurement.

Figure 5: SENTRON PAC4200.

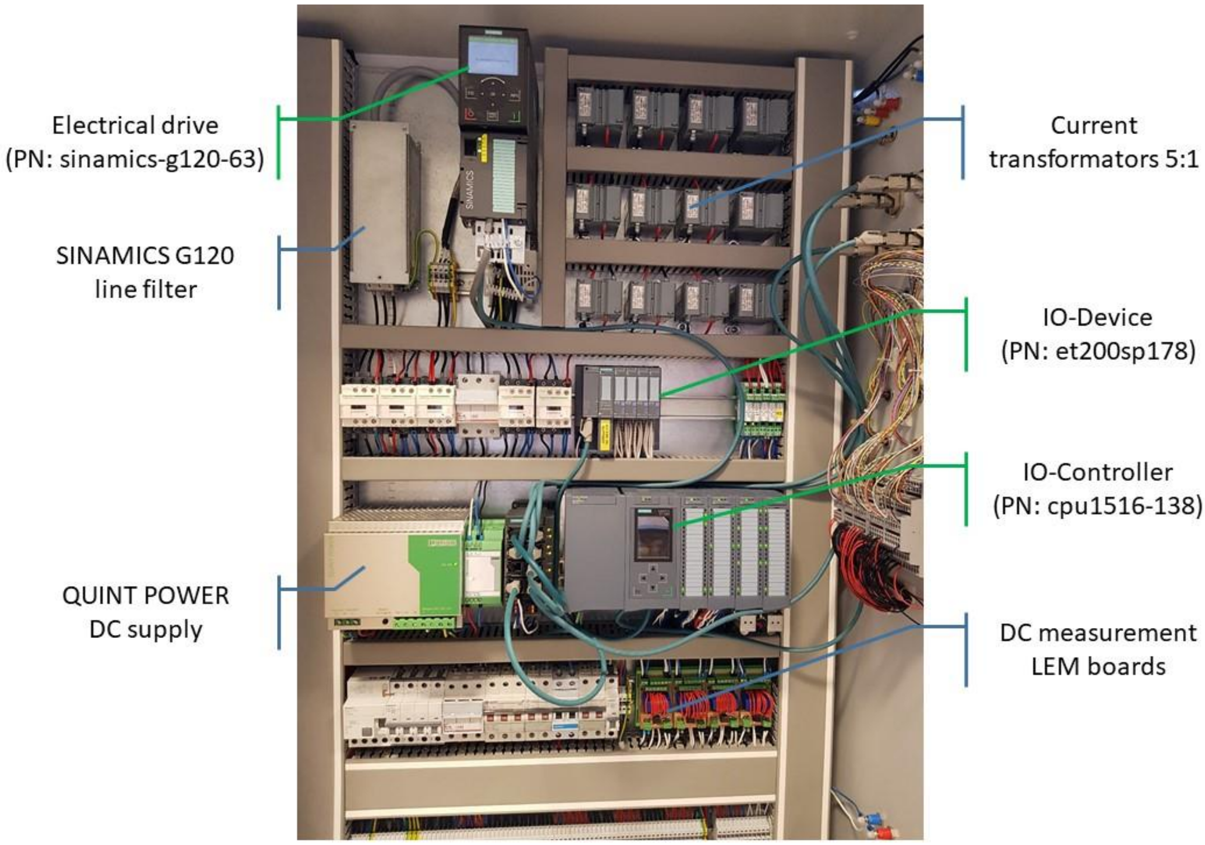


Figure 6: Detailed view inside the enclosure.

2.2 Brief network description

The PROFINET network overview can be found in Figure 7.

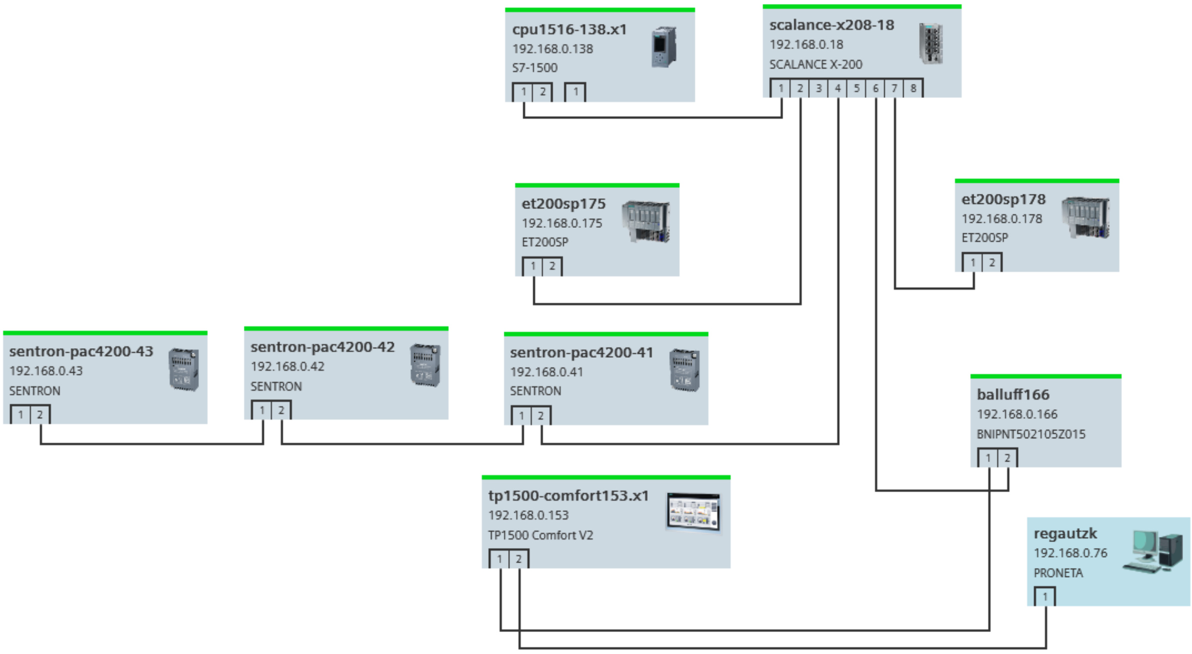


Figure 7: PE demonstrator levitation setup network overview.

An overview of the PROFINET devices can be found in Table 1 (Figure 7):

Table 1: PROFINET device overview.

Device	PN device name	IP address	PE supported?
CPU 1516F-3 PN/DP	cpu1516-138	192.168.0.138	yes
TP1500 Comfort	tp1500-comfort153	192.168.0.153	yes
SINAMICS G120 CU250S-2 PN Vector	sinamics-g120-63	192.168.0.63	Yes
IM 155-6 PN HF	et200sp175	192.168.0.175	Yes
IM 155-6 PN HF	et200sp178	192.168.0.178	Yes
SENTRON PAC4200	sentron-pac4200-41	192.168.0.41	Yes
SENTRON PAC4200	sentron-pac4200-42	192.168.0.42	Yes
SENTRON PAC4200	sentron-pac4200-43	192.168.0.43	Yes
SCALANCE X208	scalance-x208-18	192.168.0.18	No
Balluff BNI PNT-502-105-Z015	balluff166	192.168.0.166	No
SIMATIC PC station	REGAUTZK	192.168.0.76	No

An overview of the other devices can be found in Table 2:

Table 2: Other device overview.

Device name	Article	Remarks
Laser distance sensor	Balluff BOD 63M-LI06-S4 with IO-Link	
Color sensor	Balluff BFS 26K-GI-L04-S92 with IO-Link	
Base load Resistor	680 Ω	Base load, not switched off
Heating resistors	180 Ω	Main heating, PROFIenergy controlled

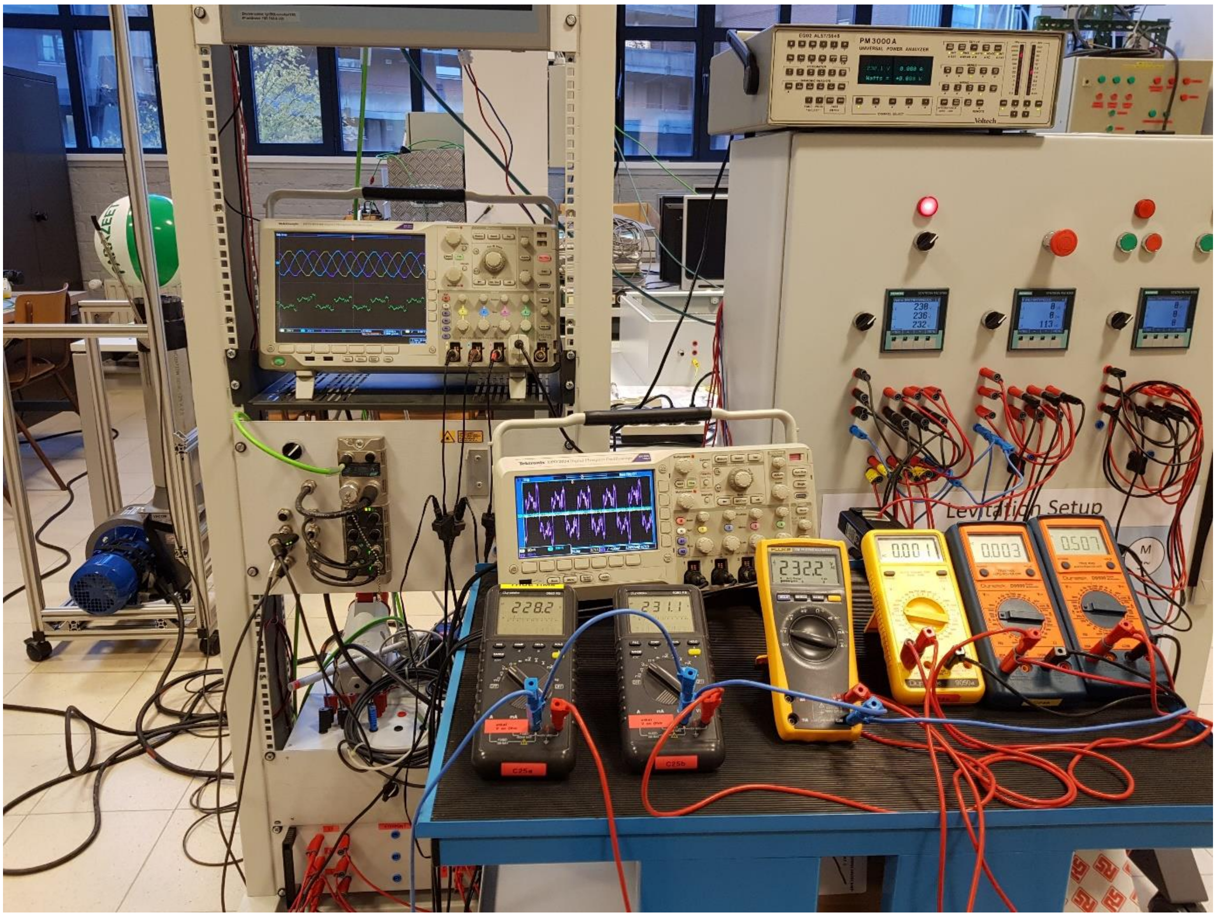


Figure 8: Typical use of measurement setup, with additional multimeters, oscilloscopes and (on top) high precision power analyzer.

During the commissioning and testing phase, additional measuring equipment was used for quick verifications, refer to Figure 8 for a typical measurement setup.

The software used in this demonstrator:

- *TIA Portal Version V15.1 update 3.*
- *WinCC V15.1 Update 3.*

3 Demonstrator modes

The following demonstrator modes are possible:

1) Unmanaged – the ball remains at a height of 500 mm during the pause, with hot air.
2) Partly managed – ball remains at a height of 500 mm but the heating resistor is turned off.
3) Fully managed – the ventilator stopped and drive is switched off.
4) PROFIenergy pause – drive, HMI screen and et200sp175 in PE pause and the AC side of the drive switched off.

The production cycle takes 9 minutes and 35 seconds and is shown in Figure 2, Figure 9 and Figure 10. The following sequence is programmed:

500 mm for 50 seconds → 1000 mm for 5 minutes → 750 mm for 3 minutes and 45 seconds.

The loads in L1 and L3 are higher resulting in a higher power factor for L1 and L3. On L2 is the drive the only load which results in a lower power factor.

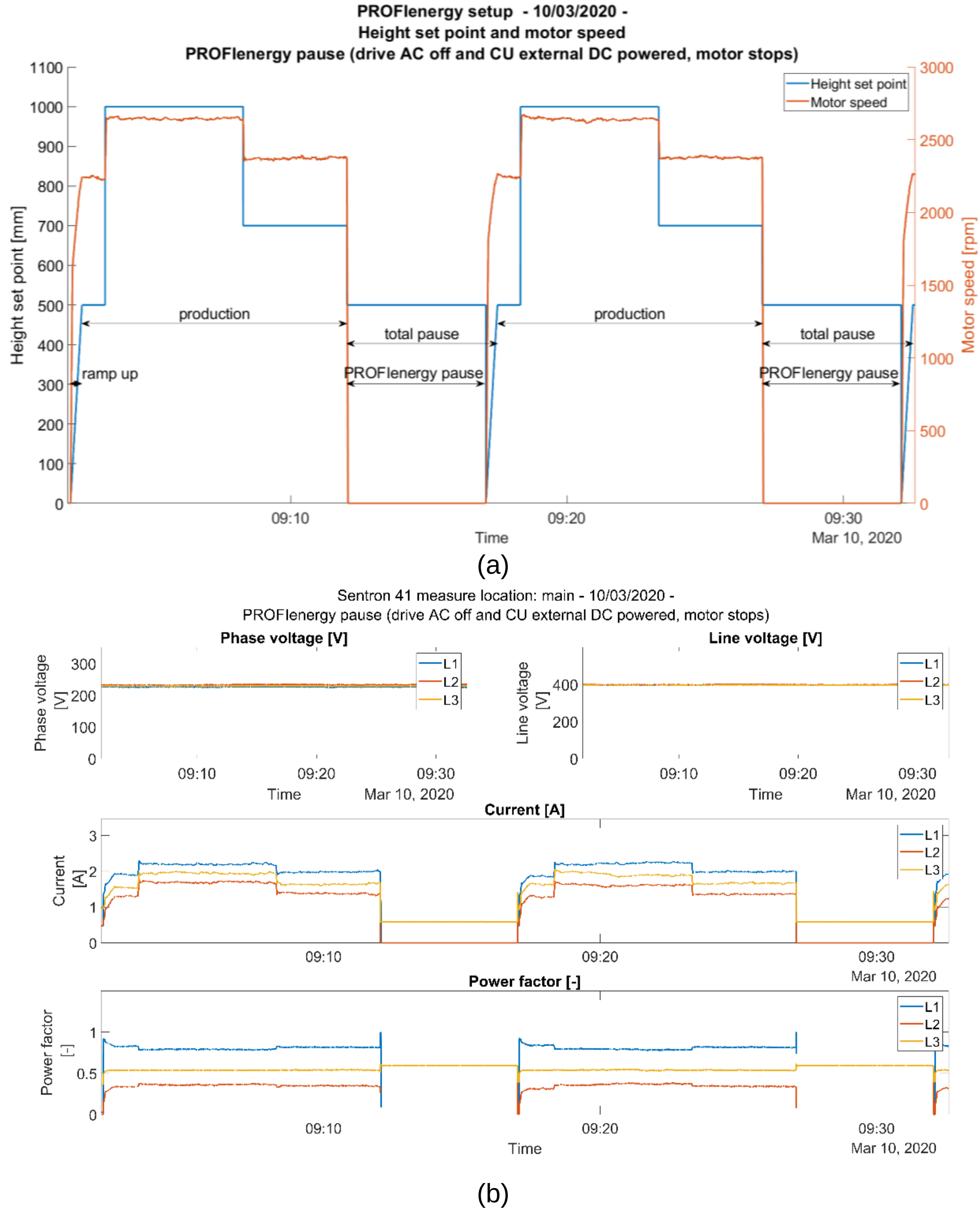


Figure 9: PROFIenergy plot (a) height set point and motor speed. (b) SENTRON 41 voltage, current and power factor measurement on the main supply of the enclosure.

The levitation sequence is explained in detail in Figure 10.

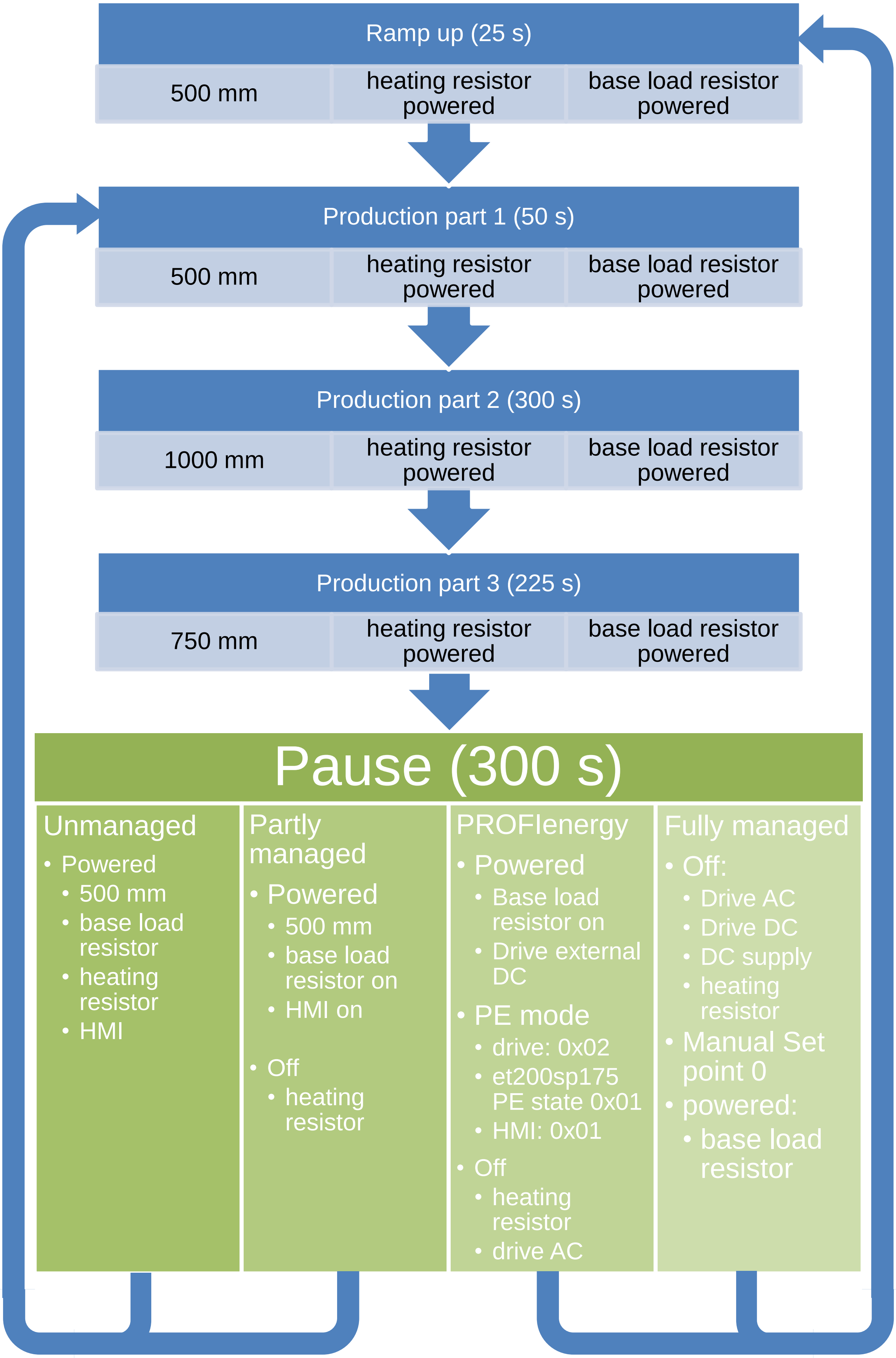


Figure 10: Demonstrator sequence.

3.1 Unmanaged pause

In this pause all the devices will remain on and the height set point is 500 mm, which is the idle state. The heating resistor still heats the air. No energy saving actions are taken into account. All components are visible in the PN network.

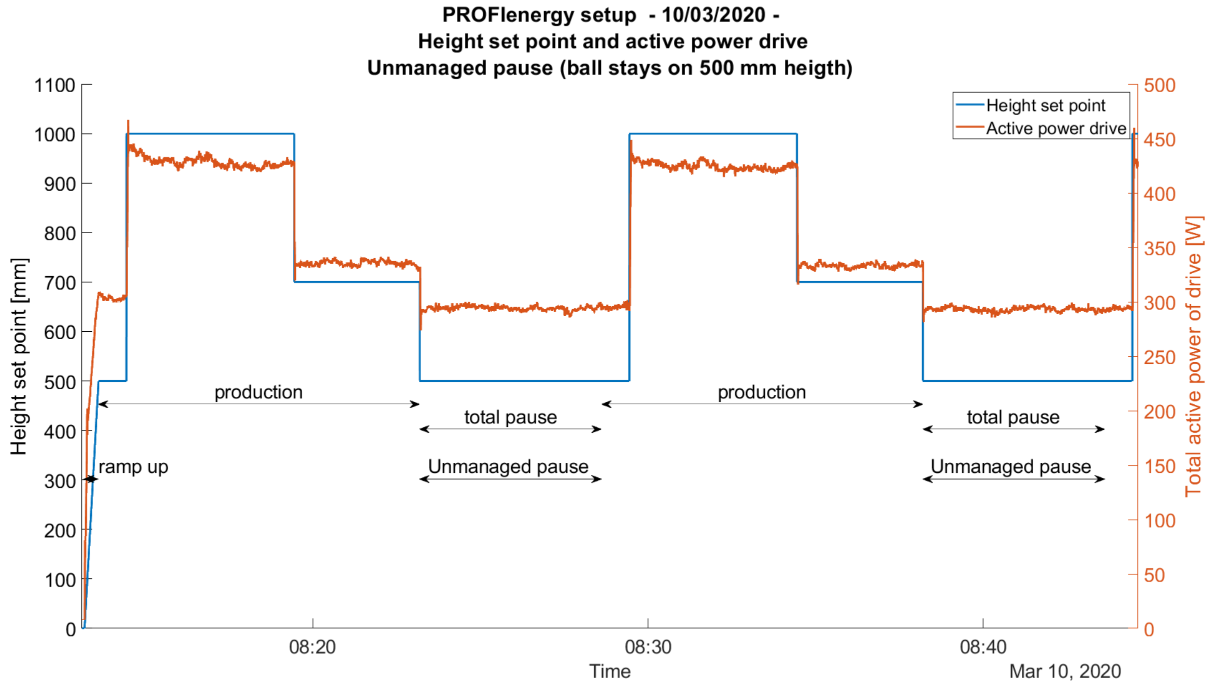


Figure 11: Cycle of an unmanaged pause (active power of the drive on the right).

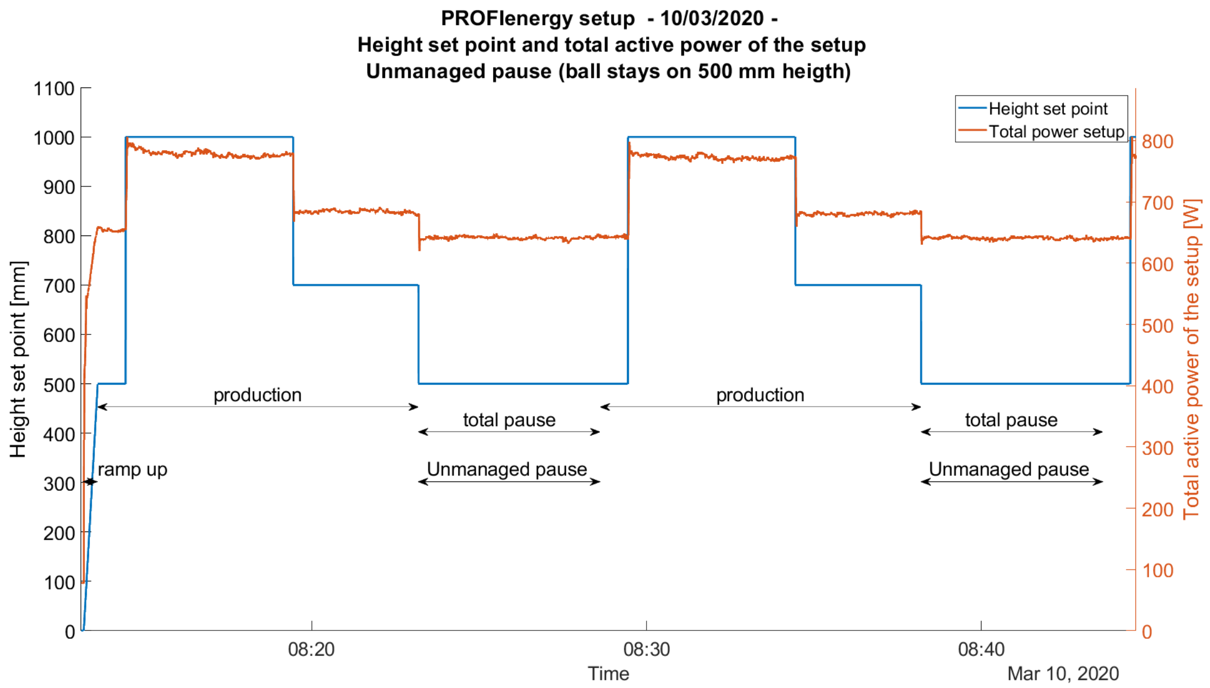


Figure 12: Cycle of an unmanaged pause (total active power of the setup on the right).

3.2 Partly managed pause

During this pause the set point is also 500 mm but the heating resistor is turned off. All the other devices keep working, and are visible in the PN network. The total active power consumption during the pause reduces from around 640 W (Figure 12) to 370 W (Figure 13). The drive power consumption is unchanged and is the same as in Figure 11.

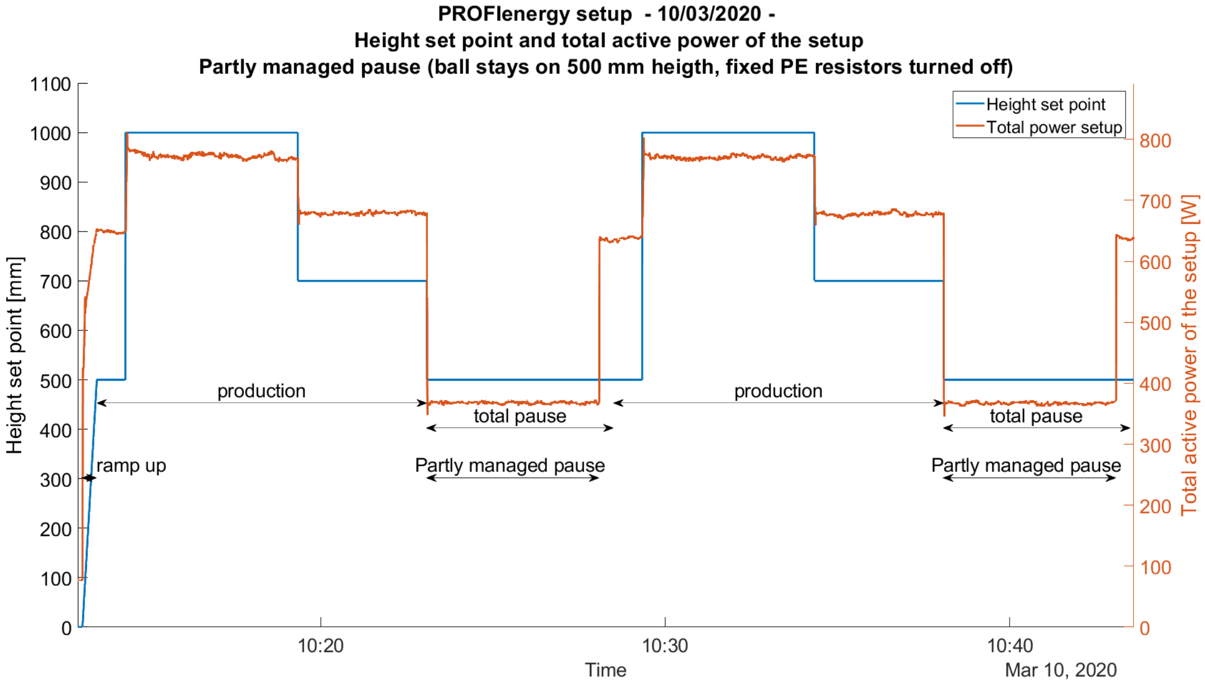


Figure 13: Cycle of partly managed pause (total active power of the setup on the right).

3.3 Fully managed pause

In the fully managed pause the drive AC and DC is switched off and the heating resistor is switched off. The HMI is powered by an external power supply which cannot be switched off. This results that the HMI is still on during this pause. After 4 minutes and 15 seconds the AC and DC is reapplied. In these 45 seconds the drive starts up and re-establishes the DC link voltage ("Drive on" time in Figure 14).
The et200sp175, et200sp178 and the sinamics-g120-63 are not reachable in the PN network during the pause.

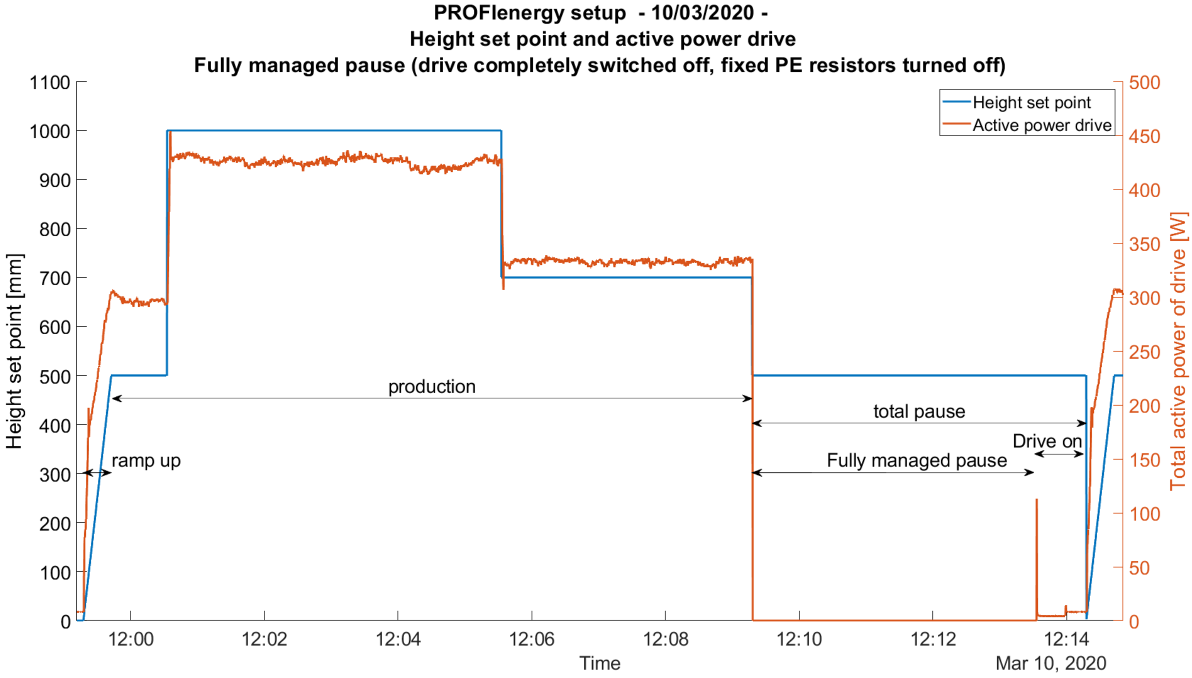


Figure 14: Cycle of the fully managed pause (total active power of the drive on the right).

3.4 PROFIenergy pause

In this pause the tp1500-comfort153 HMI touch screen, et200sp175 and the drive go into PROFIenergy pause 0x01. This means for the following components:

- TP1500 comfort panel: screen is turned off.
- Et200sp175: the inputs and output modules follow the mode parameters (proceed, shutdown, last value, substitute value).
- sinamics-g120-63: output voltage goes to zero and consumes 8,10 Wh.

In the PROFIenergy mode the heating resistor is switched off by the et200sp175 that goes to PE mode 0x01, which saves 277.2 W. The output module has mode parameter "shutdown". The G120 drive goes in PE mode 0x02 which stops the motor even if the set point and the parameter (ready state) are still set. At the end of the pause the devices listed above receive a stop pause acyclic PE command. An extra pulse is needed to follow the set point. In this demonstrator the parameter "p0840[0]" ("ready state") in the control word 1 is toggled[1].
In addition, the drive is switched off by a contactor, which is controlled by a digital output of the PLC. During the production cycle the contactor increases the power consumption by around 2 W. This power consumption is also included in the power consumption of the unmanaged and partly managed mode. The CU250S-2 PN Vector is powered by the DC supply in the enclosure, which ensures the PROFINET communication. With this addition a power saving of 7.84 W is obtained. An option is to control the contactor via an output of the drive. This output can be switched by the PROFIenergy state of the drive.

The setup consumes around 80 W (Figure 16) during the PROFIenergy pause, in this case there is a saving of around the 560 W. De drive AC side is switched off so there is no energy consumption during this pause (Figure 15). All components are visible in the PN network.

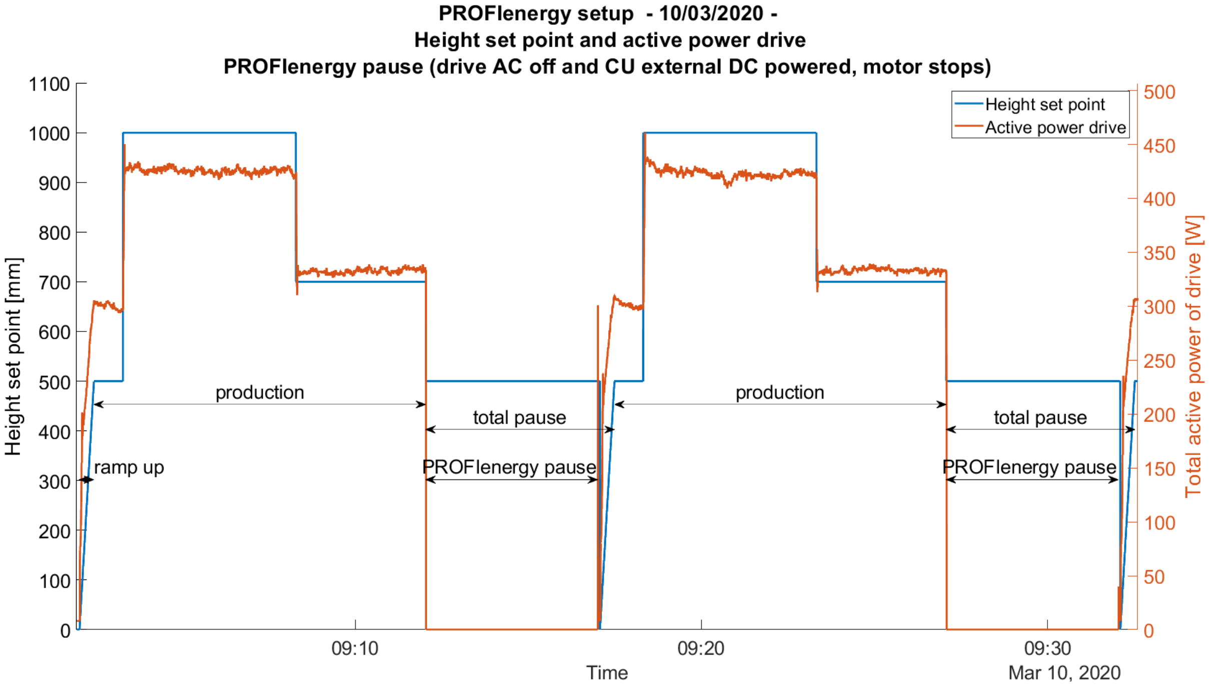


Figure 15: Cycle of PROFIenergy pause (total active power of the drive on the right).

[1] There are different options to start the drive with the Control word 1 (STW1). The different parameters can be found in the Fieldbuses function manual of the Siemens G120 drive [1]. Not all of these have been evaluated during these measurements.

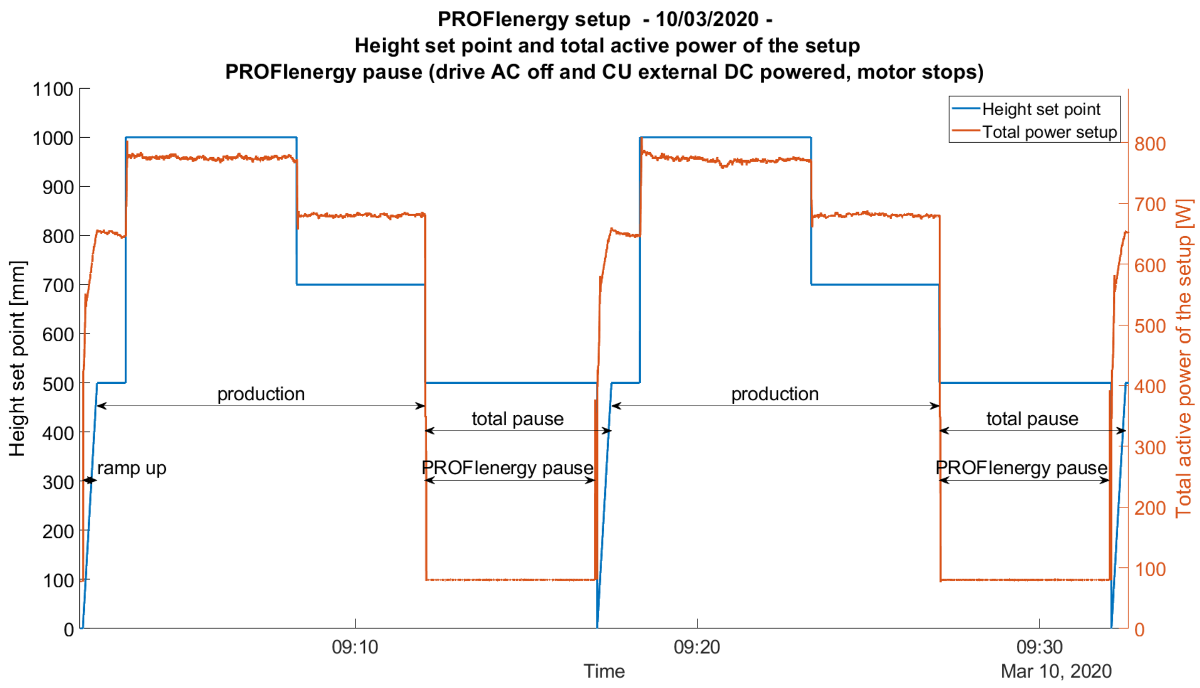


Figure 16: Cycle of PROFIenergy pause (total active power of the setup on the right).

4 Visualization

Figure 17 shows the control screen of the levitation. A trend view shows the set point and the instant and average ball levitation.

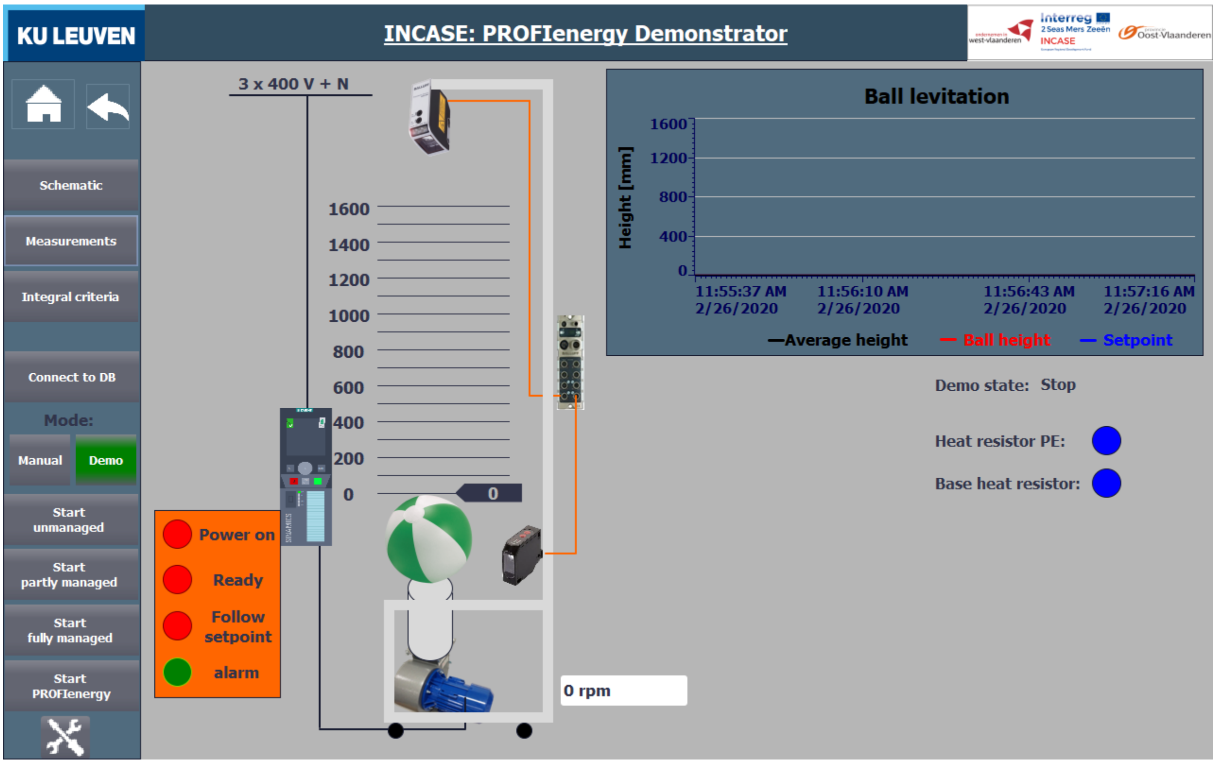


Figure 17: Control screen of the levitation setup.

Each device has a PROFIenergy screen with the following functionalities:

- Start pause with a given pause time in seconds.
- Stop pause.
- PEM (PROFIenergy Mode) status: this prompts a popup window (Figure 18) with the PROFIenergy state in which the device is currently in.
- PE identify: identifies all the functions that the device supports. The functions that are not supported are indicated with a red border and a red font color.
- Query modes: shows a window with all the PROFIenergy states that are supported in the device.
- Query version: the PROFIenergy version number will be shown in a popup window.
- Query measurement: a window shows the different measurement IDs (see Figure 19). With the “Get info” button the query measurement value information is shown in a window at the bottom of the screen.

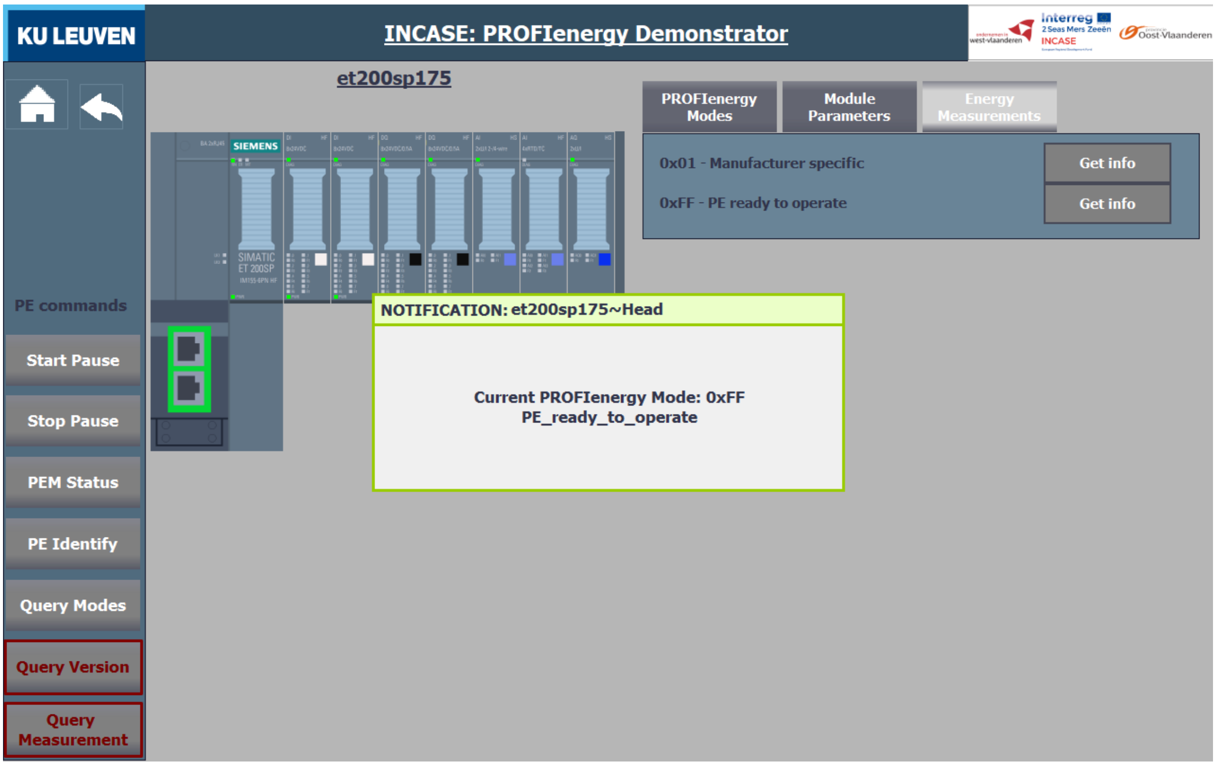


Figure 18: PEM status of et200sp175.

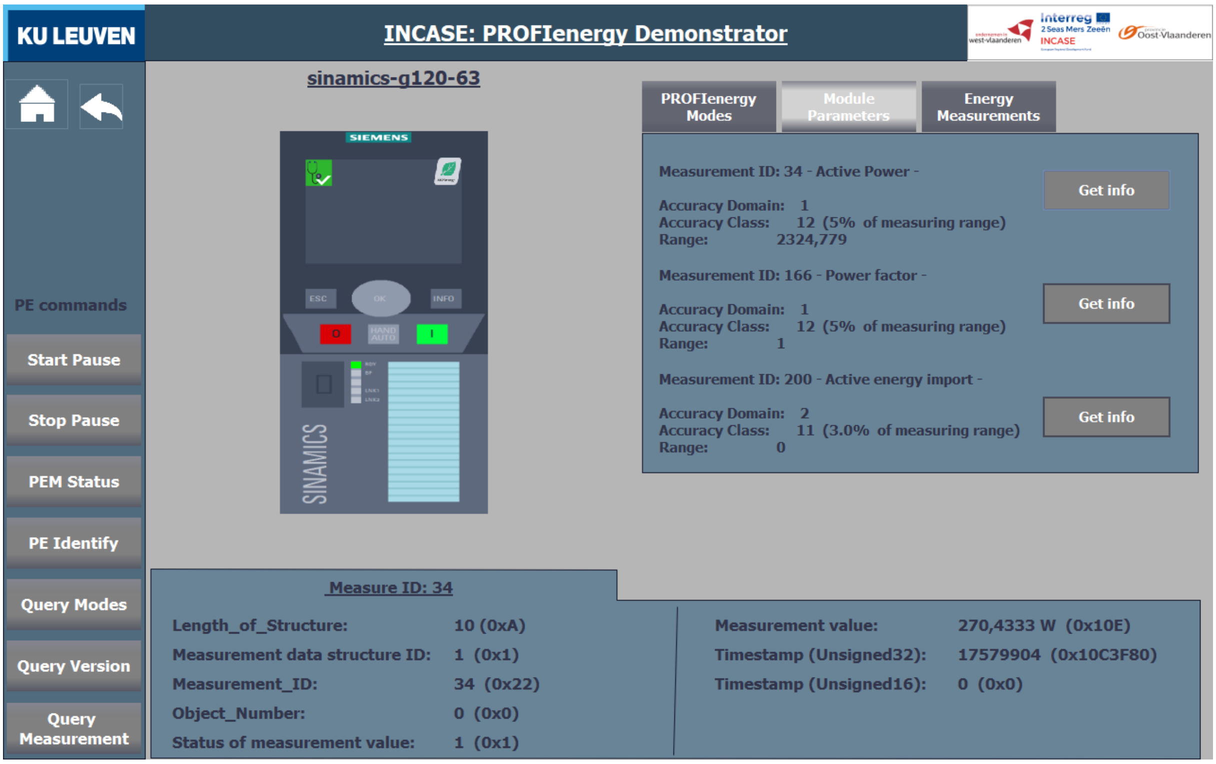


Figure 19: Query measurement list and value of the sinamics-g120-63. [1]

5 Used program files

A library was created during the programming of this setup. This library includes a PROFIenergy folder. In this folder all used PROFIenergy commands can be found in the function folder. To make use of all the functions, the “FC PROFIenergy Functions” must be called and the PROFIenergy flag “execute” of the PROFIenergy datatype must be set [2] [3] [4] [5].

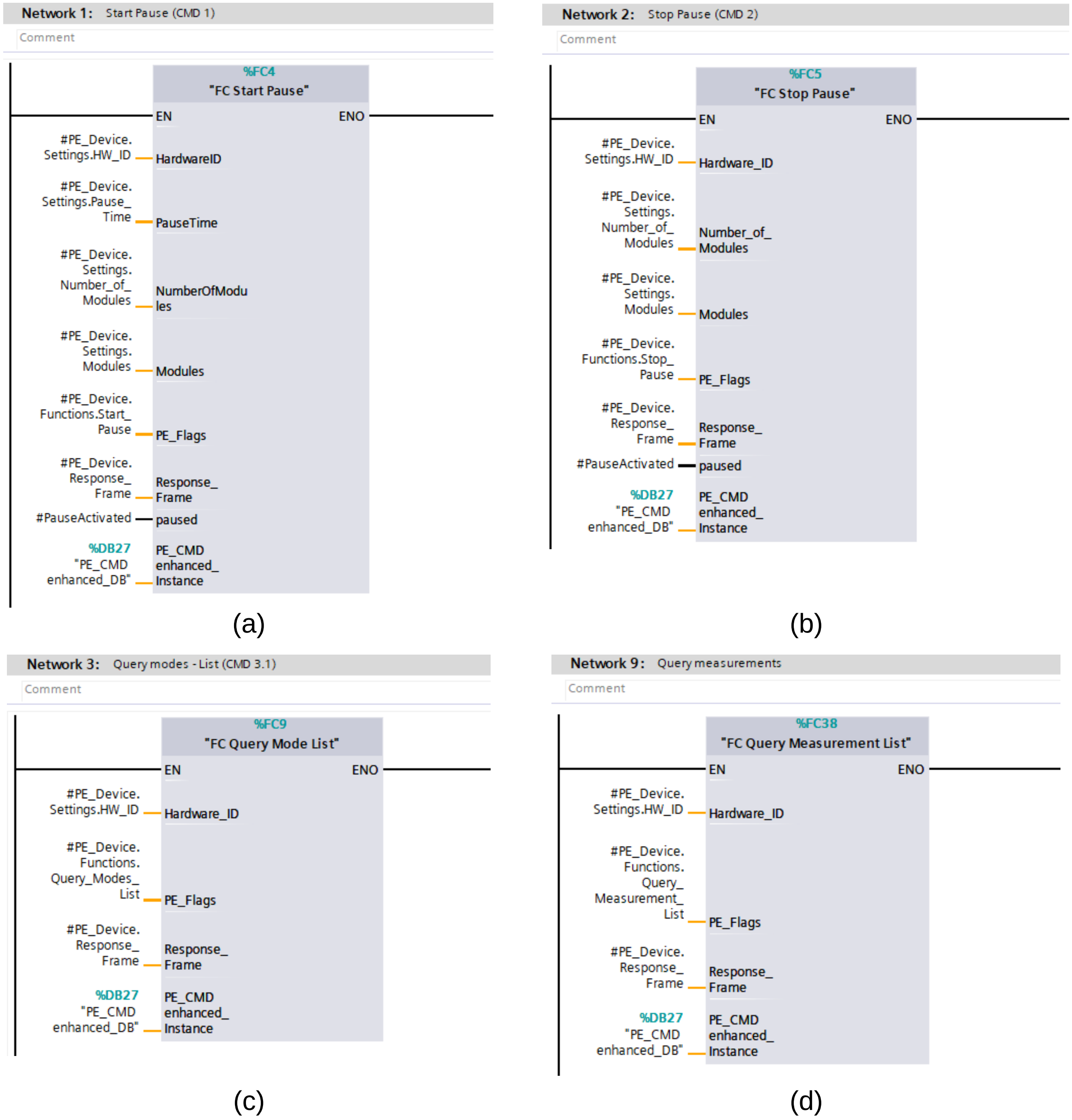


Figure 20: PROFIenergy functions in TIA Portal.

6 Results

These measurements are done with the Voltech PM3000a[2]. Refer to Figure 8 for a typical measurement setup with the Voltech power analyser. For the measurements in this paragraph the Voltech PM3000a integrator function (providing energy in Wh) is used and the sum of the 3 phases is used.

The Voltech PM3000a energy range is from 0,001 Wh to 100 000 MWh. [6]

The results in bold and italic are used as input in the calculation tool. [7]

Note: the Balluff BNI004U network block and the TP1500 comfort panel are not powered from the DC supply inside the enclosure. So if not mentioned otherwise this energy consumption is not included in the measurement. Their energy consumption is measured separately.

6.1 Main supply measurement

Table 3: Main supply measurement.

Mode	Energy (Wh)	Duration (h)	Duration (min)	Power (W)
Production cycle	129,76	0,16005	9,603	810,75
		Total pause		
Unmanaged	61,770	0,08360	5,0160	738,88
Partly managed	38,930	0,08369	5,0214	465,17
PROFIenergy	13,709	0,08363	5,0178	163,92
		Ramp up		
Ramp up	4,408	0,00680	0,4080	648,24

[2] On loan from Ghent University Campus Kortrijk during the measurement period.

6.2 Drive measurement

The following measurements are done between the line filter and the drive power module PM240-2 IP20. The 16,40 W during the PROFIenergy total pause is achieved by dividing the energy consumption of the ramp over the total pause time.

Table 4: Drive measurement.

Mode	Energy (Wh)	Duration (h)	Duration (min)	Power (W)
Production cycle	62,470	0,15927	9,5562	***392,23***
		Total pause		
Unmanaged	27,440	0,09105	5,4630	301,37
Partly managed	27,440	0,09105	5,4630	***301,37***
PROFIenergy	1,493	0,09105	5,4630	16,40
		Ramp up		
Ramp up	1,493	0,00677	0,4062	***220,52***

In Table 5 the energy consumption of the drive is measured during the “ready to operate” state and the energy saving mode 0x02. These energy consumptions are measured four times with a duration of 15 minutes. We assume that the mean (of this small number of measurements) is in both modes the same.

Table 5: Comparison drive "ready to operate" and energy saving mode 0x02.

	Ready to operate				**Energy saving mode 0x02**			
	Energy (Wh)	**Duration (h)**	**Duration (min)**	**Power (W)**	**Energy (Wh)**	**Duration (h)**	**Duration (min)**	**Power (W)**
1	2,123	0,25002	15,0012	8,49	2,121	0,24999	14,9994	8,48
2	2,005	0,25004	15,0024	8,02	1,969	0,25004	15,0024	7,87
3	1,792	0,24996	14,9976	7,17	2,039	0,25002	15,0012	8,16
4	1,924	0,24999	14,9994	7,70	1,975	0,24996	14,9976	7,90
Mean	**1,961**	**0,25000**	**15,0002**	**7,84**	**2,026**	**0,25000**	**15,0002**	**8,10**

6.3 PLC and contactor circuits measurement

Table 6: PLC and contactor circuit measurements.

Mode	Energy (Wh)	Duration (h)	Duration (min)	Power (W)
Production cycle	4,413	0,1599	9,5940	***27,60***
		Total pause		
Unmanaged	2,502	0,09035	5,4210	27,69
Partly managed	2,090	0,08355	5,0130	***25,01***
PROFIenergy	2,020	0,08319	4,9914	24,28
		Ramp up		
Ramp up	0,189	0,00671	0,4026	28,20

6.4 ET 200SP measurement

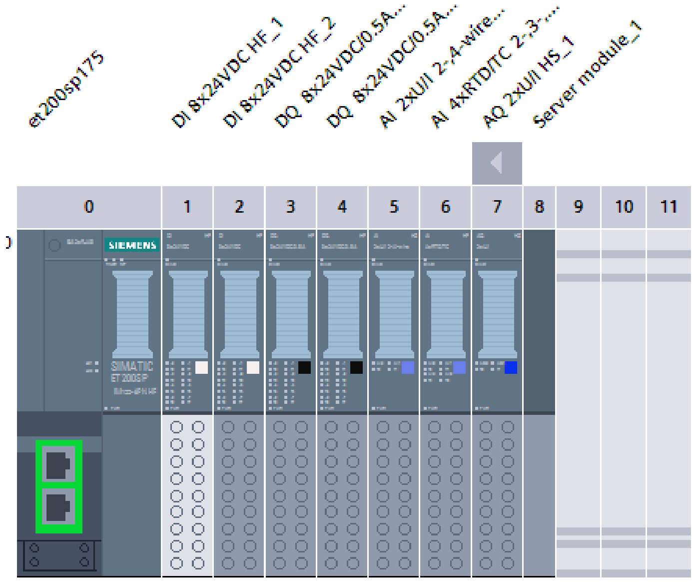


Figure 21: ET 200SP configuration.

In Table 7 the energy consumption in ready to operate and energy saving mode 0x01 is measured. The parameter mode of the 2the digital output was set to “shutdown”. The difference between the energy consumption during PE pause and ready to operate, with all outputs high on the 2the output module, is around 0.21 W. When all inputs and outputs are low the energy consumption the Voltech measured no difference. So we assume in this case that there is no difference in the power consumption if every input and output is low.

Table 7: Comparison ET 200SP "ready to operate" and energy saving mode 0x02.

	Ready to operate			**Energy saving mode 0x01**		
	Energy (Wh)	**Duration (min)**	**Power (W)**	**Energy (Wh)**	**Duration (min)**	**Power (W)**
All inputs and outputs low	2,015	15,00120	8,06	2,016	15,00120	8,06
2the DQ: all Outputs high	2,067	14,99760	8,27	2,015	14,99100	8,06

6.5 Load measurement

Heating resistor (180 Ω)		
Voltage (V)	**Current (A)**	**Power (W)**
228,8	1,2114	***277,2***

Base load resistor (680 Ω)		
Voltage (V)	**Current (A)**	**Power (W)**
229,6	0,3444	***79,06***

6.6 TP 1500 comfort measurement

The power consumption of different brightness levels and modes are measured of the TP1500 comfort panel (Article number: 6AV2 124-0QC02-0AX1) and are listed in Table 8[3].

Table 8: measurement of TP1500 comfort with different brightness levels.

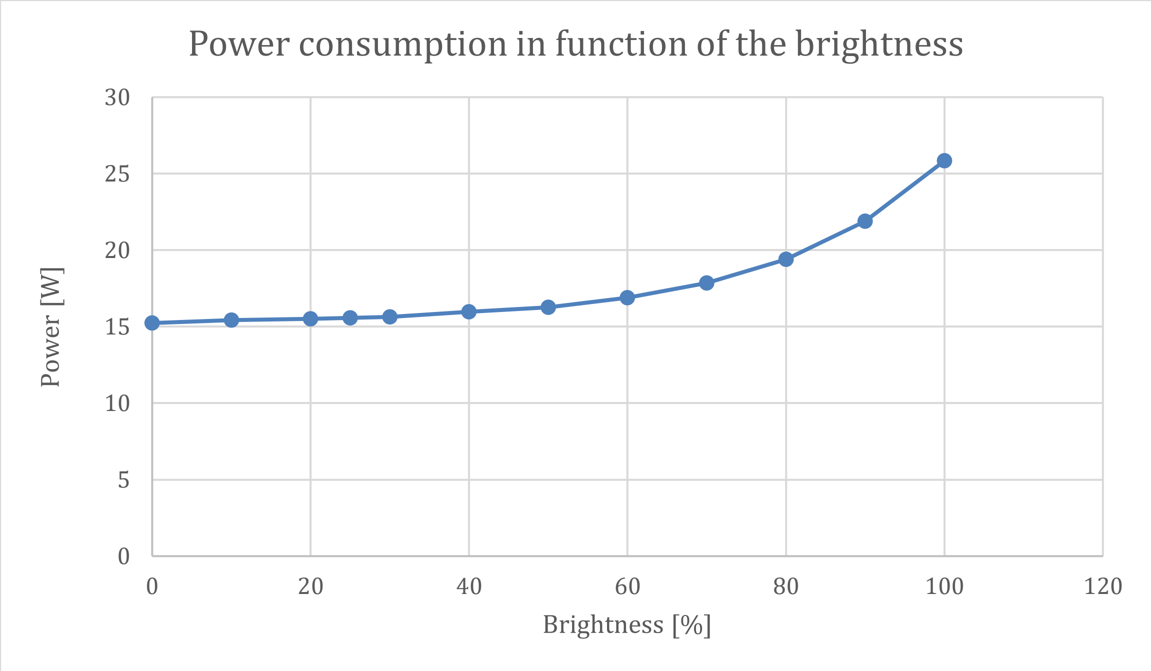
Brightness [%]	Voltage [V]	Current [A]	Power [W]
100	23,81	1,1038	***25,84***
90	23,85	0,9534	21,89
80	23,88	0,8458	19,412
70	23,89	0,7709	17,856
60	23,9	0,7212	16,888
50	23,9	0,6887	16,27
40	23,91	0,6723	15,962
30	23,91	0,6564	15,643
25	23,92	0,653	15,581
20	23,92	0,6499	15,517
10	23,92	0,6456	15,422
0	23,92	0,6376	15,235

In Table 9 the power consumption in stand-by mode and PE mode are shown. As conclusion, we assume that there is no difference.

Table 9: Measurement of TP1500 comfort in different modes.

Mode	Voltage [V]	Current [A]	Power [W]
PE	23,91	0,636	***15,194***
Stand-by	23,89	0,6374	15,218

[3] These measurements – upon request of observer partner Siemens Belgium – are at the moment of writing being studied by observer partner Volvo Cars Gent and Audi Brussels, for possible further applications.



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