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INCASE
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Output 6: PROFIenergy

D2.1.3 Report on the assessment of the energy saving potential

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This report is developed by the INCASE project partners:

Contents

Contributors to report

This report is based on research and reports delivered by several project partners.

KU Leuven:

Philippe SAEY, Mathieu TROCH, Frederic DEPUYDT, Dimitri DE SCHUYTER, Jos DE BRABANTER

University of Lille:

Jean-Marc VANNOBEL, Zakia MAADID, Zakaria MOKHTARI, Tariq MSADEK, Bilal OUALI, Kamel LADROUZ, Philippe HENNIN, Frédéric DURAK, Christophe FITER, Lotfi BELKOURA, Nicolai CHRISTOV, Bruno DAUBENFILD

Icam Lille:

Ahmed RHIAT, Lamine CHALAL, Allal SAADANE, Pierre MICHAUD, Nicolas BOULAND

Ghent University:

Jos KNOCKAERT

Thanks to UGent for the extra measuring equipment.

All contact information can be found on www.incase2seas.eu. For information about this report: philippe.saey@kuleuven.be.

The INCASE project

Industry 4.0 (I4.0) is the next industrial revolution. Manufacturers are focussing 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

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1 Executive summary

This reports contains references to literature and reworked parts of INCASE deliverables “D2.1.1 Small PROFIenergy demonstrators” and “D2.1.2 Large scale PROFIenergy pilots”. The reader is invited to consult these resources.

What is PROFIenergy?

PROFIenergy (“PE”) is a profile of PROFINET, worldwide the most used ethernet based industrial network. The PROFINET network (Figure 1) connects IO-controllers such as PLCs (Programmable Logic Controllers) with IO-Devices such as electrical drives, robots, more complex sensors and actuators, remote “islands” to which simple sensors, buttons and contactors are connected, touchscreens for HMI – Human-Machine Interface – etc.

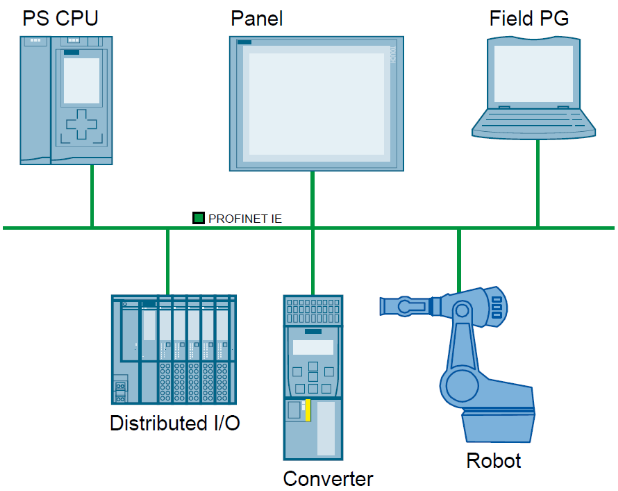


Figure 1: Example of a PROFINET network [1]

The aim of PROFIenergy is to bring (some of) these networked components to an energy saving state (a “sleep” mode) while the (rest of the) network itself remains fully functional without errors. **This energy saving state is enabled in (parts of) production cells and production lines during “idle time”, when there is no production:** during pauses, changing of shifts, when there is no night shift, (long) standstill due to errors, etc.

Who took the initiative?

The PROFIenergy profile was developed by **a group of automation vendors and end users**, upon request of (mostly) the large German automobile manufacturing plants (grouped in “AIDA”). **Initial studies found a large overall energy saving potential during pauses longer than 3-5 minutes.** The PROFIenergy idea itself **can be applied to a much wider range of manufacturing industries**, with the logical exception of among others 1) slow reacting processes (e.g. thermal inertia of an oven or a reactor) which cannot be turned off for short periods and 2) smaller simple machines and production cells that can easily be powered off (and – very important! – turned on), which can better be simply switched off. The fact that the network and the controllers remain active enables a fast start-up, often critical in – but not limited to – for example complex production lines of automobile manufacturers.

What is the energy saving potential?

The energy saving potential logically depends on how far the machine, production cell or line are already optimized for energy consumption. Initial studies – about 10 years ago – indicated a (maximum) typical energy saving potential of e.g. 33 % in a typical robot production cell in 2-shift regime ([4]).
The goals of this INCASE study are 1) to develop a calculation tool to assess the energy saving potential 2) to gather measured data on industrial components as input for a calculation tool 3) to calculate a number of use cases to find a range of energy saving potentials. All depends of course on the particular circumstances in the machine, production cell or line. Choice of typical components, pauses, etc. were done in cooperation with Volvo Cars Gent, Siemens Belgium, and other observer partners in the INCASE project.
On component level – and in 2-shift operation – we found for typical HMI touch screens an energy saving of 21 %. Volvo Cars took – inspired by the PE idea and the energy measurements in this study – the decision to always leave touch screen HMIs (that are in their case in fact only used during error searching or checking diagnostics) in sleeping mode, to be woken up only when touched. **This is strictly speaking not a PE mode, but is now being applied in the worldwide Volvo Cars automation standard: 40 % energy saving. For Volvo Cars Belgium it is a reduction of 3.600 kg of CO_2 per year (for 150 HMI panels).**
On "cell" level, using the measurements on the components in a "levitation setup", **calculations indicate an energy saving of about 10 resp. 17 %** (3- resp. 2-shift operation). Needless to mention that **this energy saving results in lower costs and reduced CO_2 emission.**

These results indicate that – for a number of applications – PROFIenergy might indeed be interesting to apply: it not only provides energy savings, but **keeps the key automation components (controllers and network) active without errors, enabling fast error-free start up near the end of the (planned) pauses.**
Further research and testing – after the INCASE project – will 1) allow for more components to be tested and more scenarios to be calculated for larger use cases in cooperation with Volvo Cars Gent 2) possibly lead to the development of a method to better design and implement in the automation environment 3) allow a closer study of the effects on diagnostic tools in the PROFINET network.

The remainder of this text is organized as follows: the PROFIenergy profile is described and original results of the initial study are mentioned in chapters 2 and 3. Chapter 4 briefly describes small scale demonstrators developed at ICAM, Univ-Lille (both located in Lille, France) and KU Leuven (Belgium) used during demonstration actions. Chapter 5 discusses the larger pilot at KU Leuven, used for measurements at component level and serving as basis for further measurements and calculations. Finally, the calculation tool (chapter 6) was used to calculate the energy saving potential for different scenarios in chapter 7.

2 Introduction

Europe 2020[1] is a strategy proposed by the European Commission in March 2010. One of its main targets is energy related: to reduce greenhouse gas emissions by at least 20% compared to 1990, to increase the share of renewable energy in primary energy consumption to 20%, and to achieve a 20% increase in energy efficiency Figure 2. The energy-related targets most probably will be achieved, except for the efficiency increase and energy consumption decrease, as indicated in Figure 4.

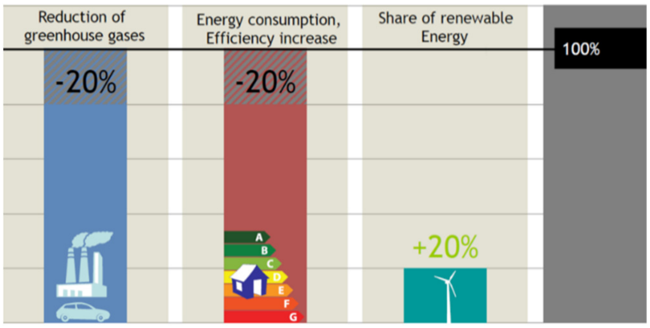


Figure 2: Energy-related targets of the EU 2020 strategy [2].

In order to comply with the "EU 2020" strategy, energy consumption needs to decrease even more (Figure 4), also in the manufacturing industries. PROFIenergy [3] has been developed upon request of the German car manufacturing industries (Figure 3), to reduce energy consumption during production standstill (pauses, weekends, nightshift without production etc.).

A more comprehensive study on advanced standby strategies in automobile production can be found in [4].

Figure 3: PROFIenergy was developed upon request of the German car manufacturing industries [5].

[1] http://ec.europa.eu/eu2020/pdf/COMPLET EN BARROSO 007 - Europe 2020 - EN version.pdf

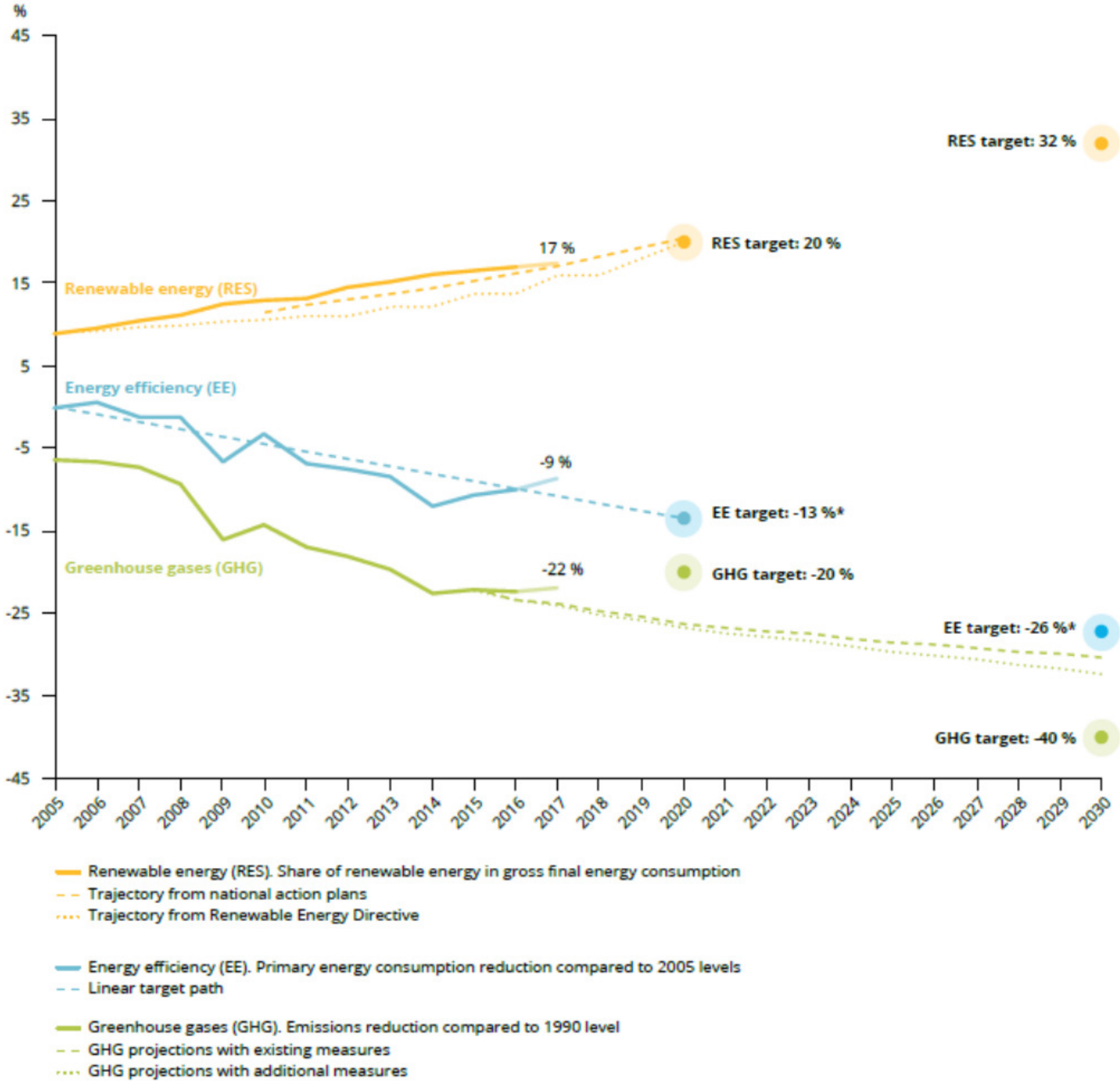


Figure 4: EU progress towards 2020 and 2030 targets on climate and energy [6].

3 PROFIenergy overview

3.1 Operating principle of PROFIenergy

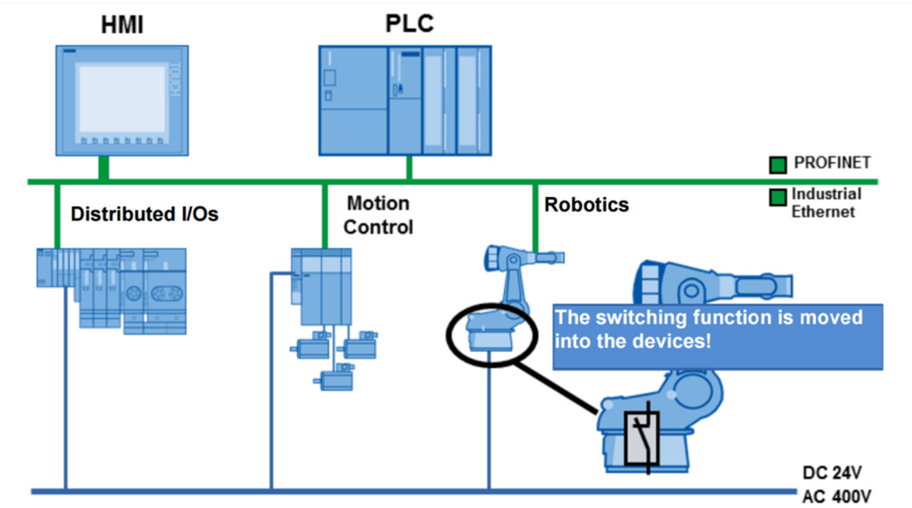


Figure 5: Typical components of a PROFINET/PROFIenergy network [7].

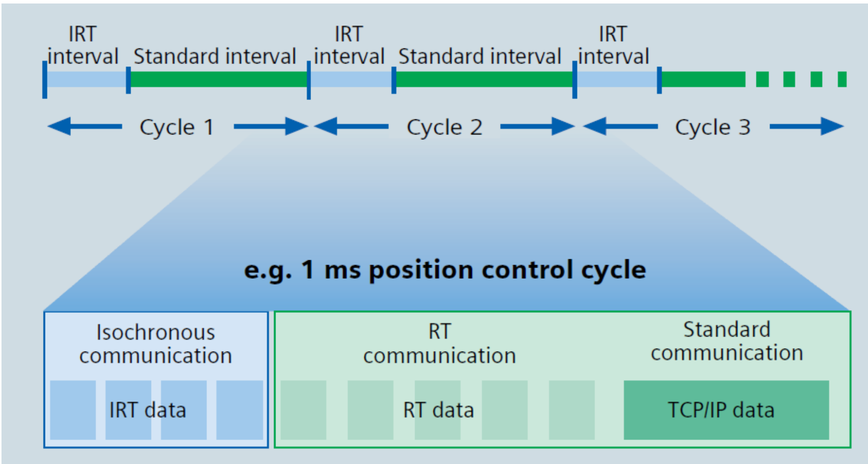


Figure 6: Typical composition of a PROFINET cycle [8].

The PROFIenergy profile enables sending PROFIenergy commands (e.g. to bring a device to energy-saving mode) to multiple IO-devices in the PROFINET industrial ethernet. PROFIenergy can be entirely integrated in existing PROFINET configurations. By using acyclic communication, PROFIenergy commands do not interfere with the cyclic (fast, more deterministic) PROFINET IRT and RT communication (Figure 6); PROFIenergy commands are sent in the “standard” communication time frame.
Commands can be programmed in the same IO-controllers that are already used to control the plant.
Switching on and off is achieved within the IO-devices themselves, no additional switching hardware is required (Figure 5).

The operating principle is quite simple. The IO-controller sends a command to the energy consuming device containing the duration of the offline state. The device then autonomously executes the corresponding commands in its energy profile (Figure 7, Figure 8 and Figure 9).

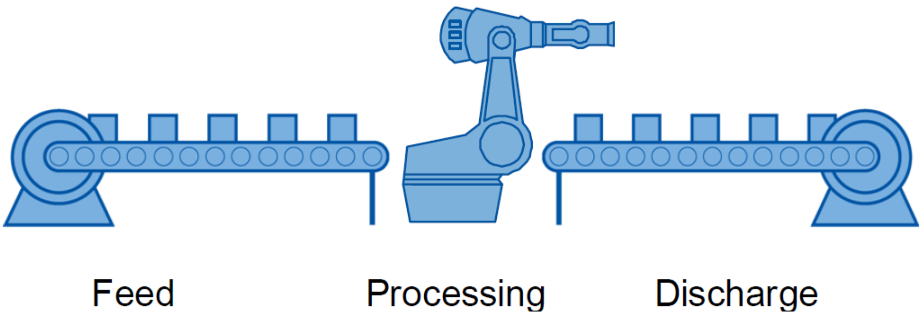


Figure 7: Simplified layout of the industrial process used for the schematic of Figure 8 [9].

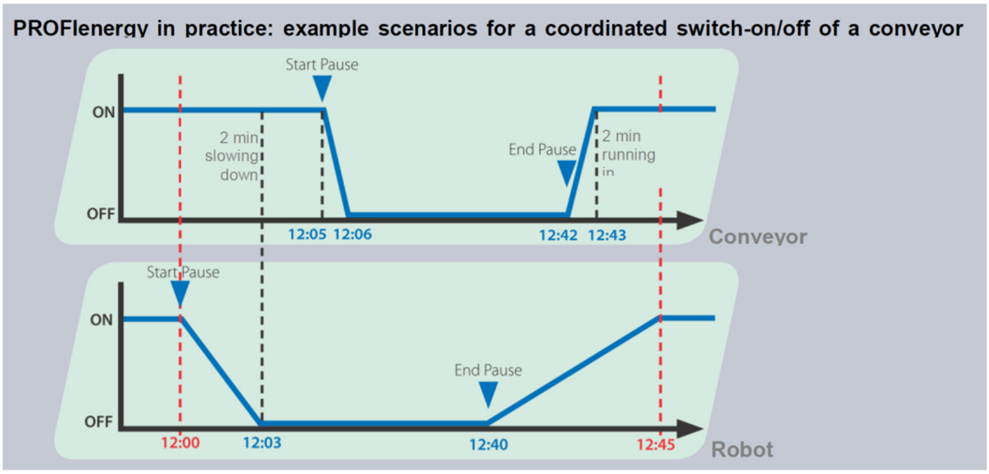


Figure 8: Energy saving mode of the robot-conveyor of Figure 7, showing coordinated switch on/off [7].

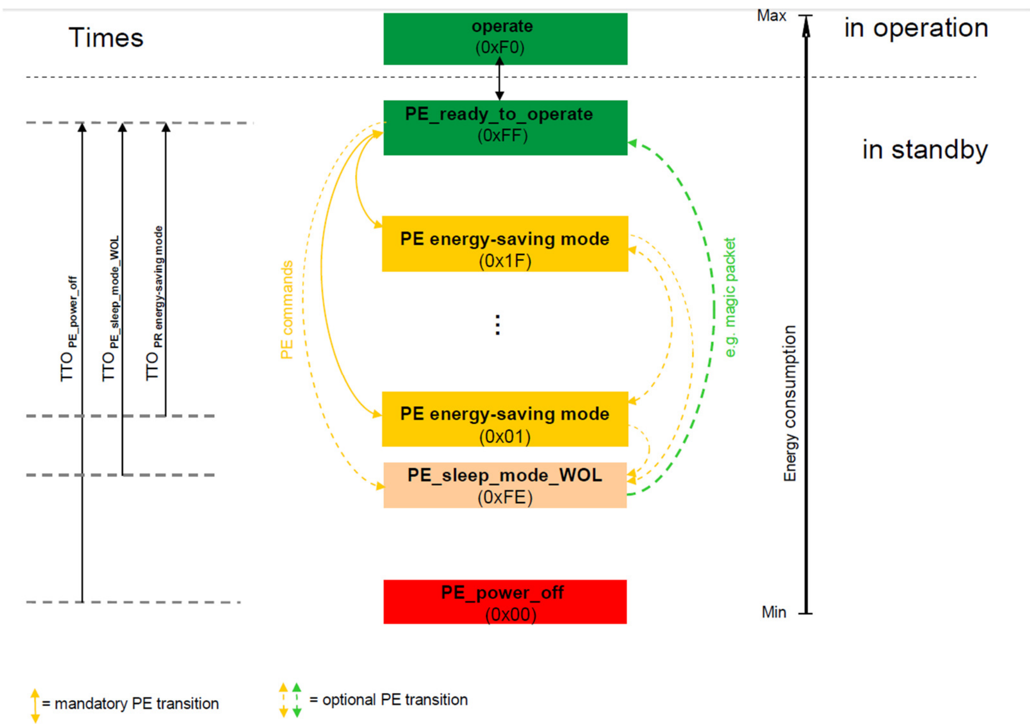


Figure 9: PROFIenergy state diagram and timeline [10].

In order to switch back to the normal operating mode, another message is sent over PROFINET. In fact, the user requires just two commands in its program. This way, control logic commands can stay separated from energy management commands. Integrating

PROFIenergy commands does not enlarge the volume of user settings, no additional addresses are required in the process image. New commands can be used in existing program libraries and factory standards, without influencing them.
Since switching on and off is achieved in the IO-device itself, users can decide themselves on how to switch off certain devices. For example, the motor in a conveyor belt could ramp down instead of braking.

PROFIenergy consists of two control commands, ‘start_pause’ and ‘end_pause’ (see Figure 10). With the ‘start_pause’ command, the controller forces the device to a state of lower energy consumption. This command contains a tPause_Time, the duration of the pause, which is a criterion to decide if the device switches to the PROFIenergy mode. If the pause duration is less than the minimal pause time, the device will not change its operating mode. If the pause duration is exceeded, the device will not automatically switch back to its ‘PE_ready_ to_operate’ mode. If multiple PROFIenergy modes exist within the device, it will automatically select the optimal mode in which most energy can be saved in the available timespan.

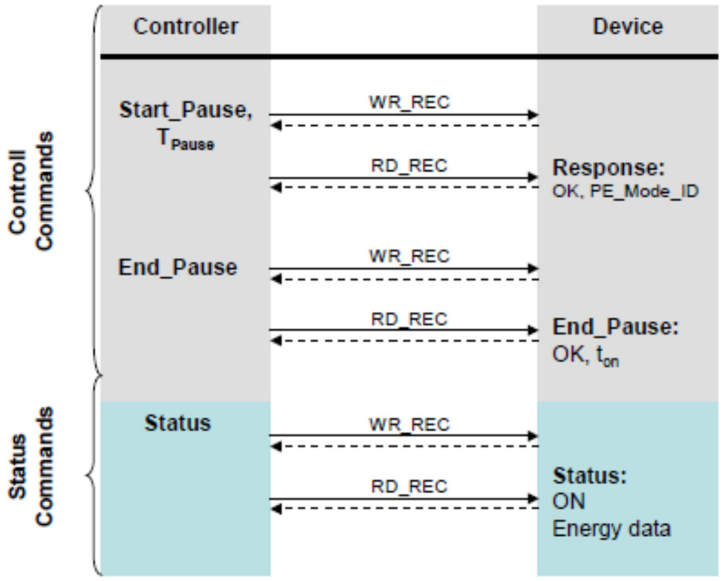


Figure 10: Overview of messages during a typical PROFIenergy cycle [8].

3.2 Typical use cases

PROFIenergy is used for both planned as unplanned pauses or for the collection of energy consumption measurements. Four use cases have been defined [7].

- **Use case 1: Saving energy during short pauses**
  Short pauses can be coffee breaks, lunch breaks or changing a shift. They are from a few minutes up to one hour long. The aim is to save energy during the production-free time without jeopardizing system availability. It is also possible to switch off only some of the consumers during short pauses. If the complete production power is needed at the end of the pause, it is supplied without delay.
  Therefore, the amount of energy saved is less than in use case 2.

- **Use case 2: Saving energy during longer pauses**

Typical pauses of this kind are nights and weekends. Since these pauses are considerably longer, additional consumers can be shut down into energy-saving mode. Even processes with longer start-up phases such as (small) heating processes can be addressed. Since the duration is longer, a larger amount of energy can be saved during these pauses. It is also possible to switch complete units into energy saving mode.

- **Use case 3: Saving energy during unscheduled downtimes**
  This type of pause (downtime) has logically not been planned or scheduled. The point in time and the duration of such an interruption cannot be foreseen. Nevertheless, we also want to save energy in this case. Such interruptions occur, for example, if the flow of material is interrupted. Since the user program can also coordinate complex correlations between units, it is also possible to optimally save energy in such situations.
  Since in such a case, the duration of the downtime cannot be foreseen, it is first classified as the shorter use case 1 for not to affect a quick change-over to the production phase. Should it turn out that the downtime will take longer, it is possible to change to use case 2.

- **Use case 4: Measuring and visualizing the energy flow**
  PROFIenergy also allows for reading out data such as the actual electric power or the energy consumption of the devices in a uniform format. During operation, these data are collected and can be displayed and analysed. This ensures that the measured variables as they are nowadays available in frequency converters or motor starters, for example, are available to the user for further processing in a uniform format and structure. These PROFIenergy functions thus form the basis for an active load and energy management during operation.

Some devices can’t be turned off for a set period of time and then be turned on again, as this would waste energy (e.g. thermal processes). Safety related equipment and large continuous processes (e.g. thermal ovens, blast furnaces, petroleum crackers, etc.) are obviously not suited for short or even longer shutdowns.
In longer pauses (hours to days) devices can be turned off completely (power off) if the start-up is short and straightforward (typically small standalone machines). However, when dealing with complex start-up routines (e.g. a car production line), it might be interesting to leave the controller and network connections active, thus allowing a smoother start-up.

3.3 General advantages

PROFIenergy is an open standard that holds many advantages in different areas.
A lot of time can be saved during installation, because it’s a PROFINET profile, whereas older energy saving systems are usually client specific and hardware based, complex and sometimes patented.
With PROFIenergy, switching on and off is achieved within the IO-device itself.
The return on investment is relatively high due to the large saving potential and low investment cost.

Energy measurements can be communicated to the PLC, which in some cases allows reducing power peaks.
Finally, PROFIenergy does not only address the largest consumers but also the many smaller devices in manufacturing plants.

3.4 Estimated energy saving potential

3.4.1 Case study at Daimler and Volkswagen car manufacturing plants

PROFIBUS International in combination with the University of Cologne has conducted research to the energy saving potential of PROFIenergy. The goal of the measurement campaign was to actually measure cost benefits of the PROFIenergy protocol through energy savings and possible increase of life expectancy of the IO devices in the production line. The goals set were to:

- save and analyse load profiles in a typical manufacturing process
- analyse energy consumption of individual components
- locate large energy consumers
- check the effect on energy consumption during different action profiles
- search the minimal useful pause length for relevant energy savings.

We present some results of the study in the next paragraphs.

Figure 11: Typical setup of power analysers during the measurement campaign in a car manufacturing plant [5].

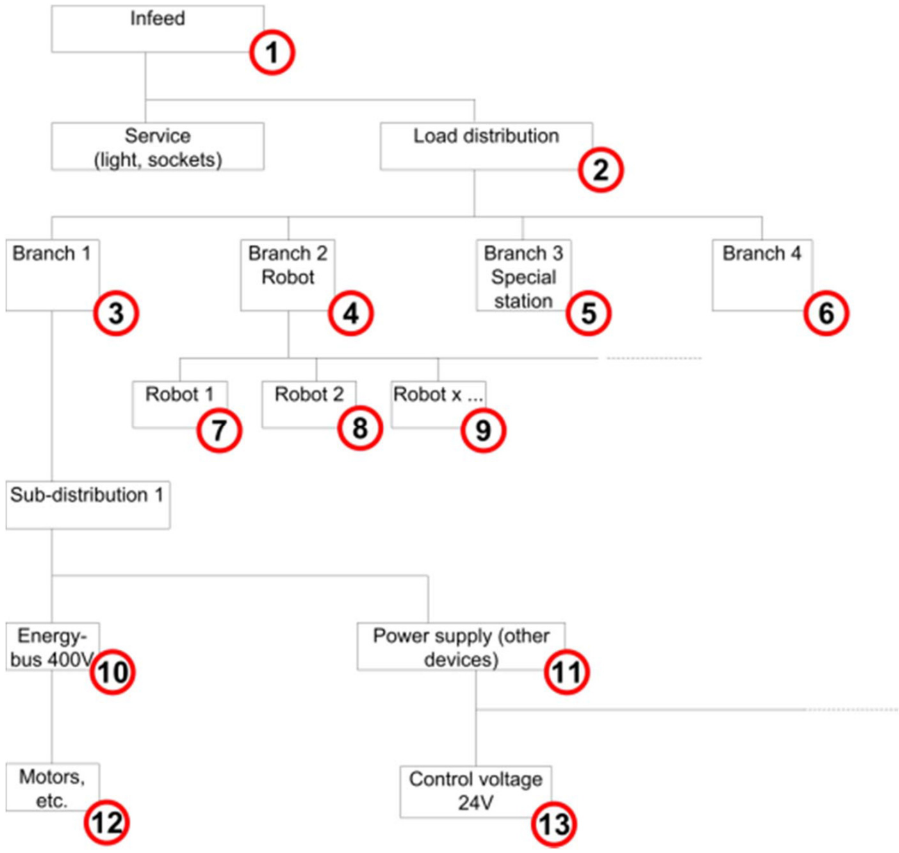


Figure 12: Typical layout of measurement points during the measurement campaign [5].

These measurements, taken in Germany at the Daimler and Volkswagen factories [5], enabled analysing the load, spread of load and typical types of pauses. With measurement equipment spread in the factory, different types of loads could be checked in different steps of the manufacturing process. Nominal, maximum and mean energy usage was measured for entire production cells, in different sections and for all devices within the production cell.

From these measurements, an overview of the large production pause times in the factory (weekend, lunch break, etc.), the duration of unplanned pauses (due to malfunctioning equipment, faults, etc.) and actual duration of maintenance pauses were acquired. Using this information, conclusions were made about the energy saving potential of different kinds of pauses.

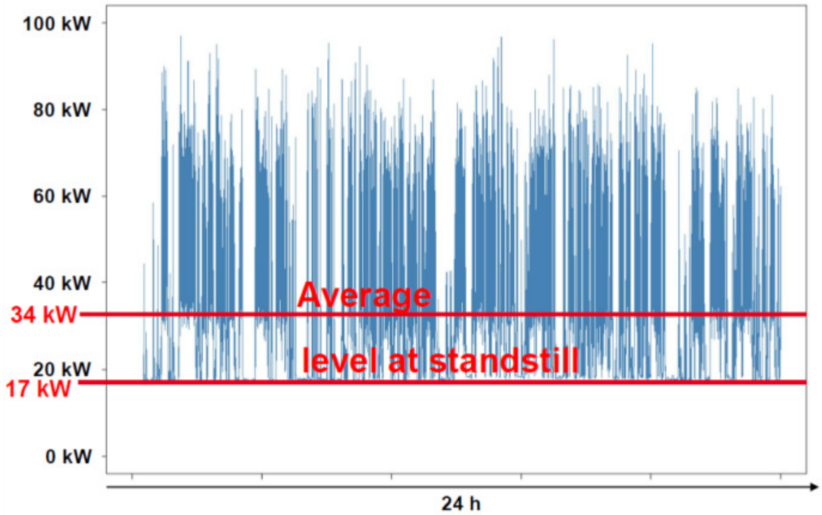


Figure 13: Instantaneous power fluctuations during a 24 hour logging in a production cell [11].

Over the course of 24 hours, a lot of peaks in the power consumption are observed (Figure 13). Maximum load is about 80 kW while during standstill the power consumption is still about 17 kW. Figure 14 and Figure 15 show Sankey diagrams of the (average) power used by the different production cell components during production resp. standstill. The robot is the largest consumer in the production cell; the robot requires 18.51 kW during production, and still uses 35% of that power (6.16 kW) during standstill. The entire production cell uses 17.74 kW during standstill, and 32.62 kW during production.

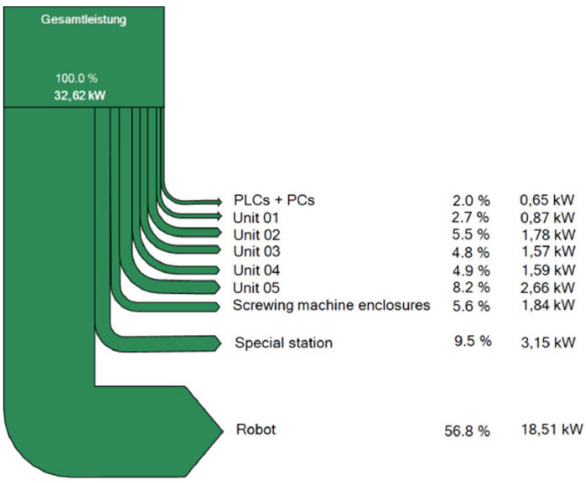


Figure 14: Sankey diagram of power required during production [5].

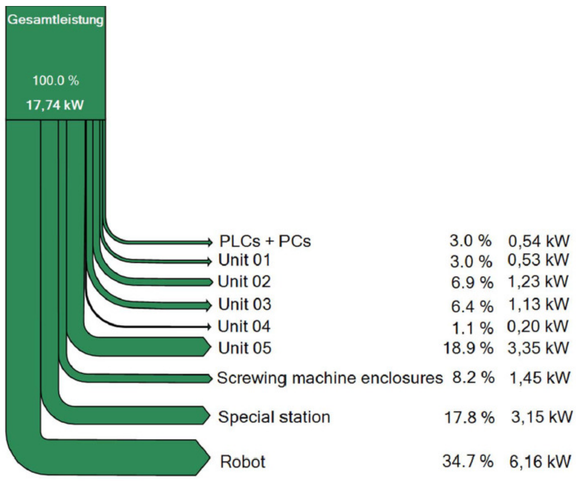


Figure 15: Sankey diagram of power used during standstill [5].

3.4.2 Analysis of pauses

Pauses have different causes, such as lunch breaks, holidays, maintenance, breakdowns, shortage of material, etc. Since most breakdowns happen at start-up of machinery, engineers are more prone to keeping their production lines fully operational, which clearly has a negative effect on energy consumption. An analysis of duration and energy saving potential is needed; Figure 16 shows the distribution of pauses in the investigated production cells.

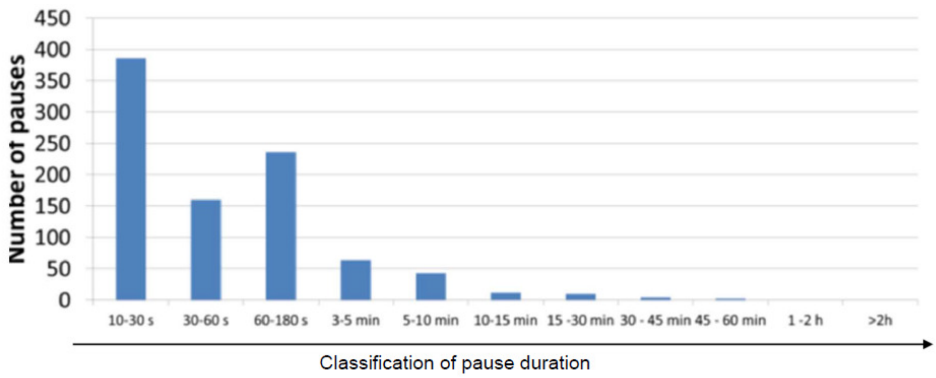


Figure 16: Analysis of pause duration [5].

For the car manufacturing plants under investigation, pauses from 3-5 minutes and longer are found to be economically interesting for using PROFIenergy standby modes. Shorter pauses are not interesting, since starting and stopping the production cell or line takes time and energy. The cumulative pause times are found in the graph of Figure 17, indicating that 64% of the total standstill time is economically interesting for PROFIenergy standby modes.

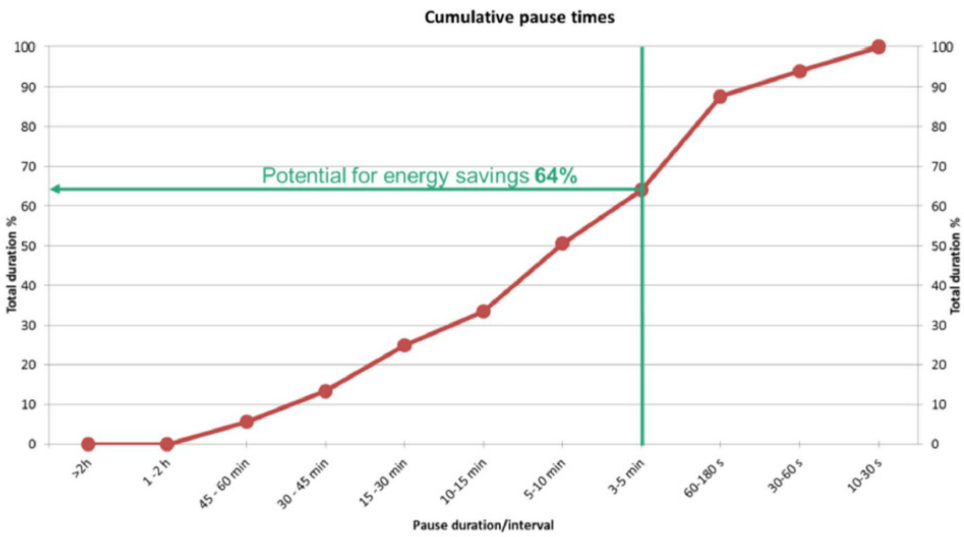


Figure 17: Cumulative pause times [11].

3.4.3 Potential energy and cost savings, and resulting CO2 reduction

Based on the Klasen study [5] in a typical car manufacturing plant with a 2-shift operation, almost half of the energy is used during pauses. In the considered production cell, energy consumption during pauses is equal to about € 162 per week.

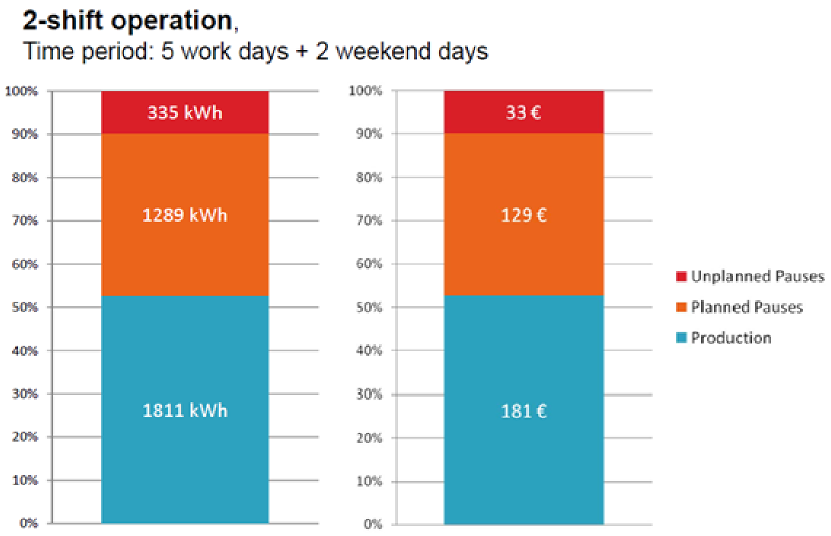


Figure 18: Energy consumption and costs in 1 week [5].

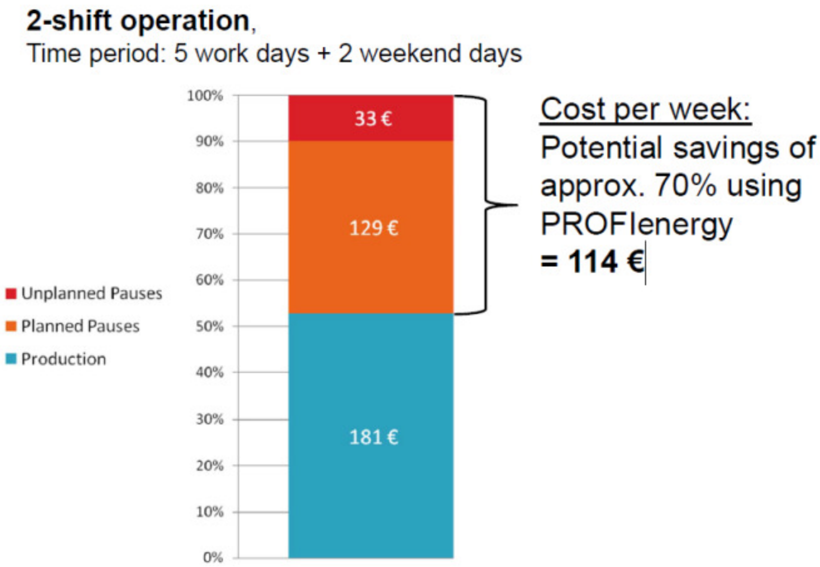


Figure 19: Potential weekly savings with PROFIenergy [5].

If we assume PROFIenergy to be able to take advantage of 70% of the pause time then savings up to 33% could be achieved. This means implementing PROFIenergy could save up to € 114 per week.

On a yearly basis, nearly € 6000 could be saved. An overview on yearly basis can be found in [12]. Finally, the resulting decrease in CO2 emission is presented in Figure 20; CO_2 emission is estimated at 0.59 kg/kWh[2].

Table 1: Extrapolation of the measurement campaign to a yearly basis [12].

Σ Energy [kWh]	Energy savings potential [kWh]	Σ Energy cost [€]	Savings potential Energy cost[€]	Σ CO-Emission [kg]	Savings potential CO-Emission[kg]	Savings potential in relation to total amount of energy[%]
172 750	57 000	17 250	5 700	100 450	33 250	33

[2] Typical German fuel mix in that period, prior to closing the nuclear power plants.

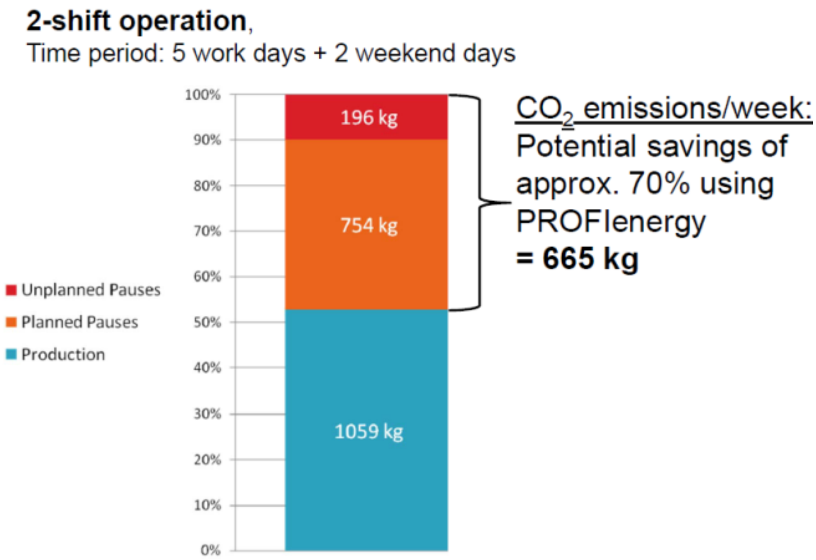


Figure 20: Potential weekly reduction of CO2 emissions [5].

4 Small scale demonstrators

4.1 Test bench with LEDs and protocol testing - KU Leuven

The first version of the small scale demonstrator for PROFIenergy explores the basic behaviour of fairly standard components, such as IO Controllers (PLCs) as "remote I/O" (IO Devices). The software functions to achieve the PROFIenergy behaviour have been programmed and tested.

In this application only the total current to the ET200SP remote IO Device (Siemens) was measured. The 24 V_{dc} load consisted of relays switching LEDs and load resistors, as "visual demonstration". Actual loads of course differ from application to application.

Figure 21: Small demonstrator set-up with PLC (left) connected to remote I/O (left), controlling electricity users (green modules before remote I/O).

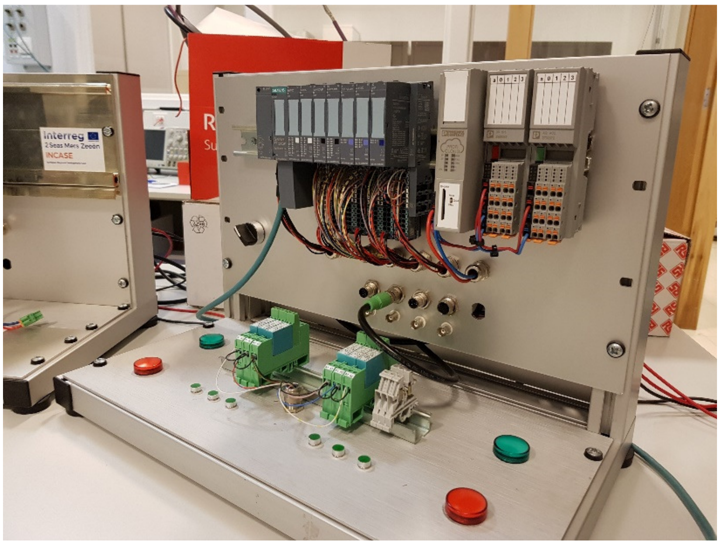


Figure 22: Detail of the switched loads.

Figure 23: Overview of the set-up when measuring consumed current/power.

For the current measurements, a DPO 4054B oscilloscope and a TCP312A current probe from Tektronix were used.

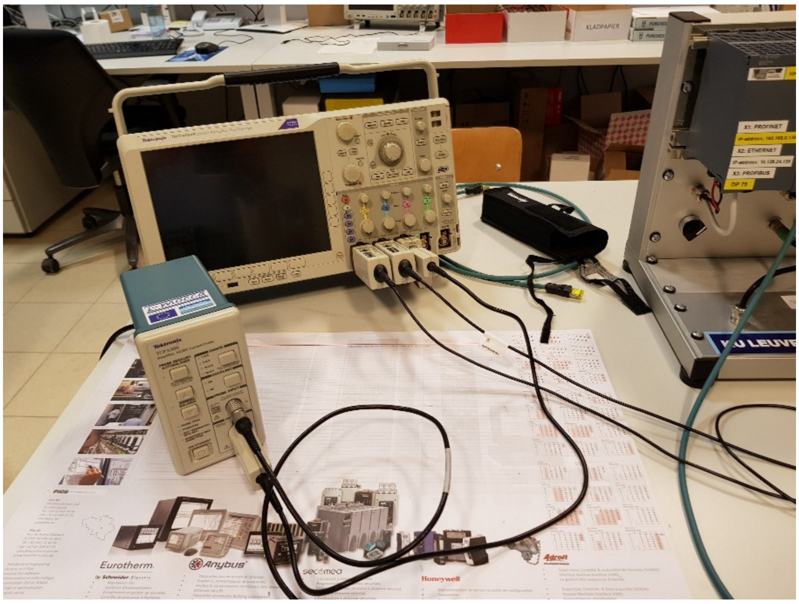


Figure 24: Detail of the oscilloscope with current sensing probe.

The oscilloscope was set-up to trigger on a current falling edge to detect the start of the PROFIenergy command, showing the original current to the ET200SP in the pretrigger part, and the lower current when PROFIenergy is enabled. The original current was 544 mA, the current during standby mode 400 mA; only one input and one output module was disabled by the PROFIenergy command.

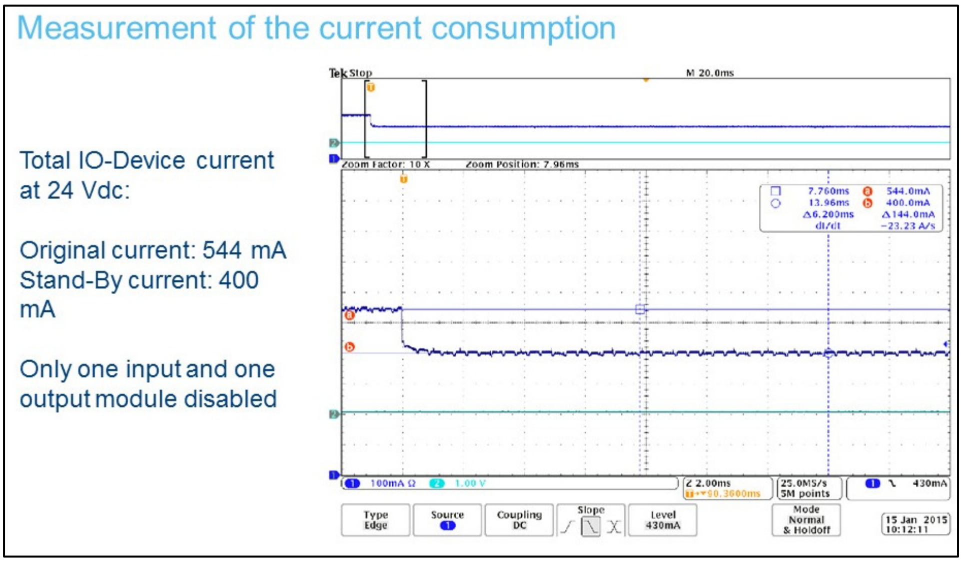


Figure 25: Initial current/power saving, with only small loads being switched off.

In addition to the current measurement, the communication between IO-Controller and distributed IO-Device for the start and end command of the PROFIenergy state was also analysed. An overview of the typical messages exchanged between the IO-Controller and a distributed IO module is shown in Figure 26.

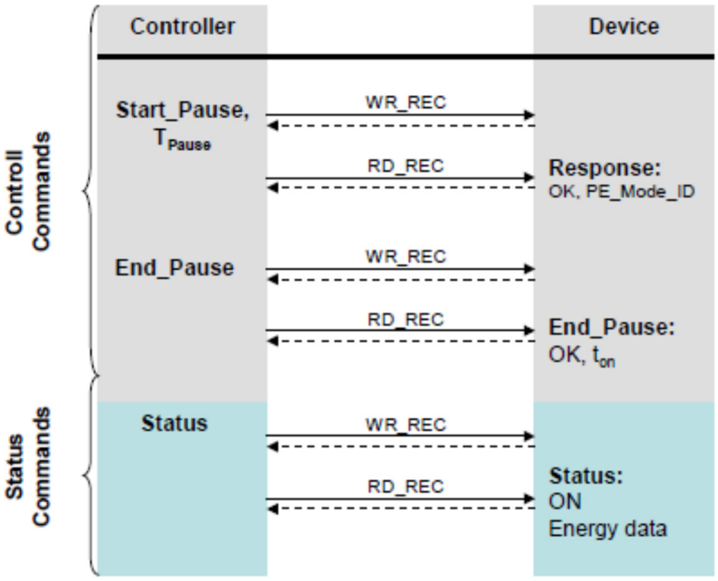


Figure 26: Overview of messages during a typical PROFIenergy cycle [8].

To start and stop the PROFIenergy state, 8 UDP messages are sent, 4 sent by the controller and 4 by the distributed IO.

The IO-Controller initiates the sequence by sending the start command which is displayed below. This is a write command: PROFIenergy has to be started and the time it has to stay in this state of lower energy consumption is communicated.

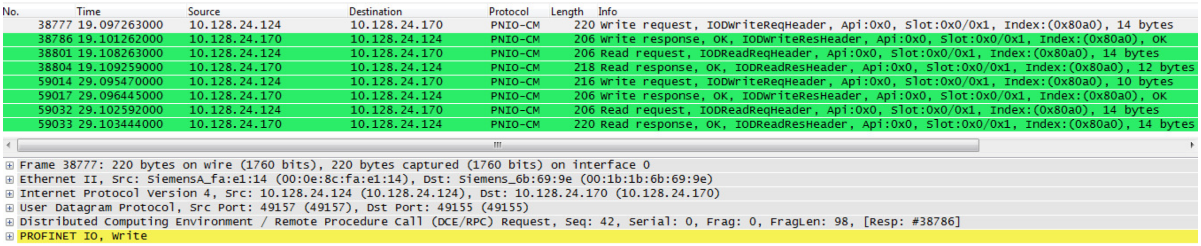


Figure 27: PROFIenergy messages intercepted with Wireshark.

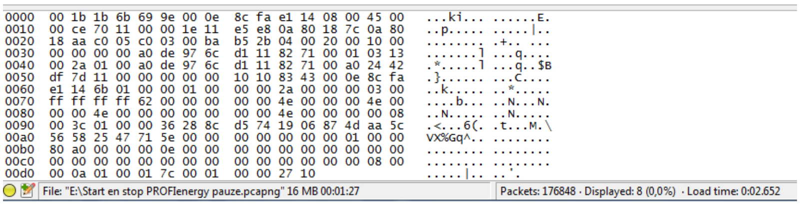


Figure 28: Detail of a PROFIenergy message intercepted with Wireshark.

Next, the IO-Controller will send a read request on which the slave answers with its actual values.
To end the PROFIenergy state, another write command is sent containing PROFIenergy information and the command to end the energy saving state.
Finally, the controller sends another read command in order to know if the device really left its energy saving state.

4.2 Small motor setup - University of Lille

University of Lille 1 has built a physical demonstrator to show the PROFIenergy protocol benefits by measuring the electric energy consumption of an asynchronous motor in case of different energy saving scenarios.

A SIEMENS S7-1200 PLC is used to control the power cut of this asynchronous motor. This is done using a PROFINET CU250S–2 PN Control Unit with Operator Panel (IOP) coupled to a SINAMICS PM240-2 inverter.

Energy consumption is measured by a PAC4200 through a 7KT1200 current measurement unit and data sent to the PLC through the PROFINET network.

At last, a KTP600 HMI reports the results to the end user.

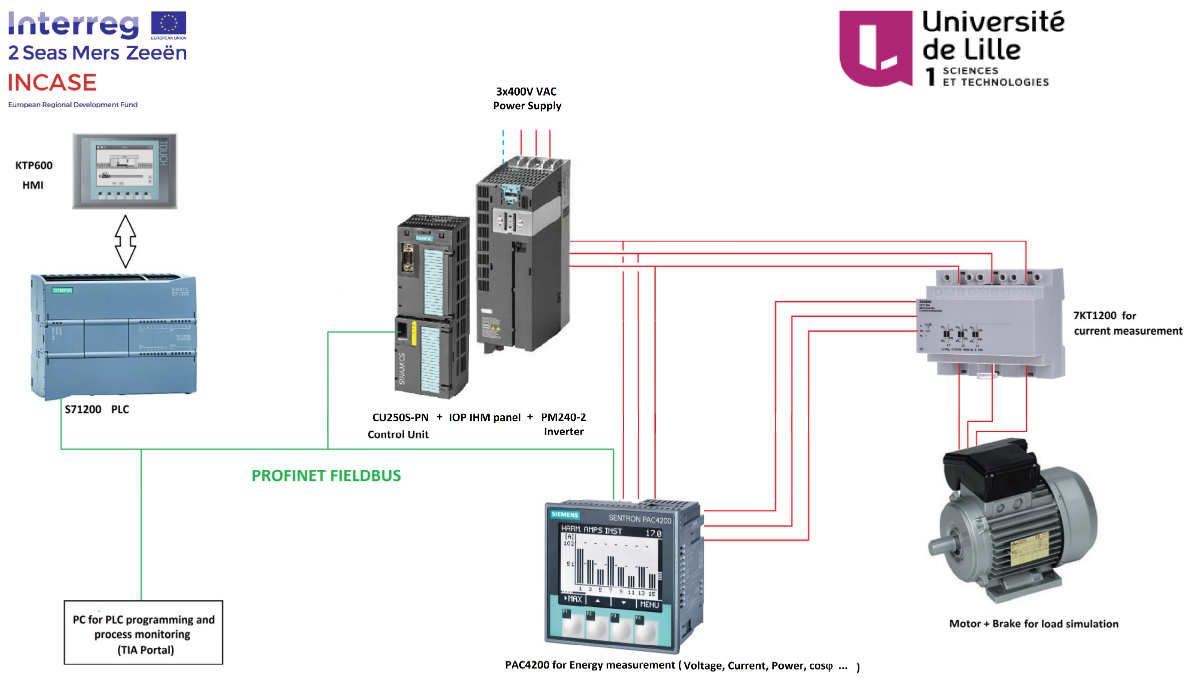


Figure 29: General overview

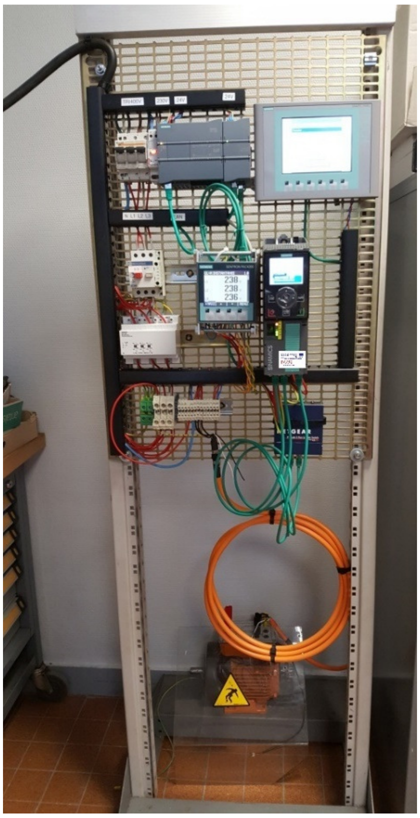


Figure 30: Overview

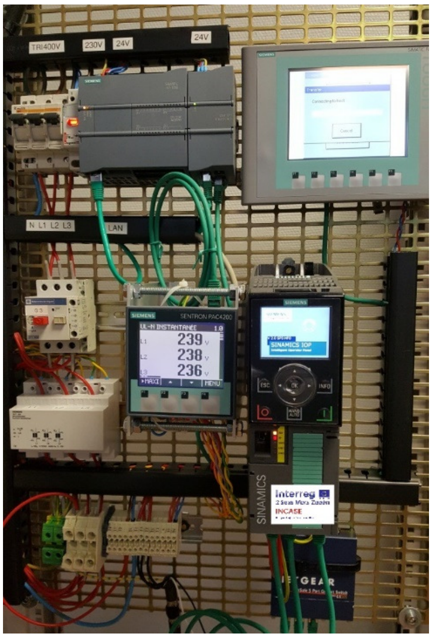


Figure 31: Detail

4.3 I4.0 Compact Trainer - ICAM

The I4.0 Compact Trainer from Festo is an interesting setup to demonstrate I4.0 topics. Figure 32 gives on overview of the machine. The Figure 33 shows a detailed architecture.

By controlling some parts of this machine, namely the PLC + Drill, the conveyor in combination with the built-in power analyser, a demonstration of PROFIenergy technology is straightforward. Figure 34 gives the sketch of this scenario.
This work shows the potential of this machine to develop very significant demonstrations on I4.0 topics.

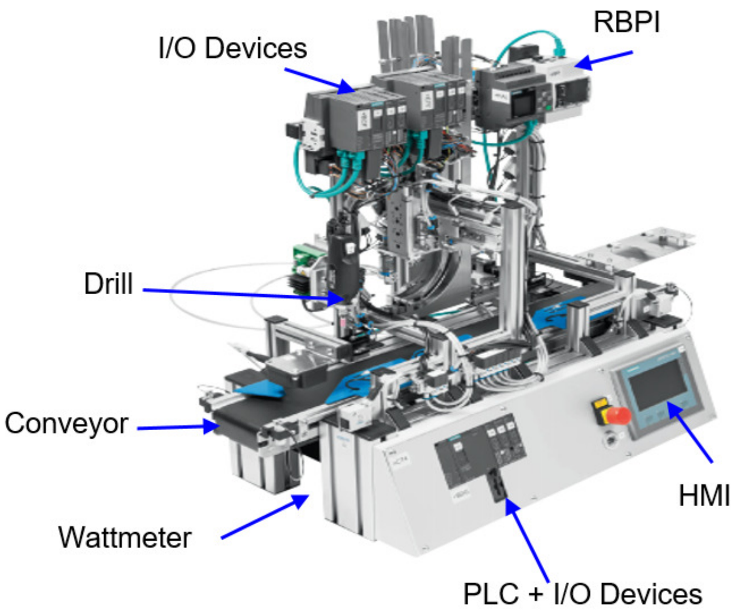


Figure 32: I4.0 Compact Trainer from Festo.

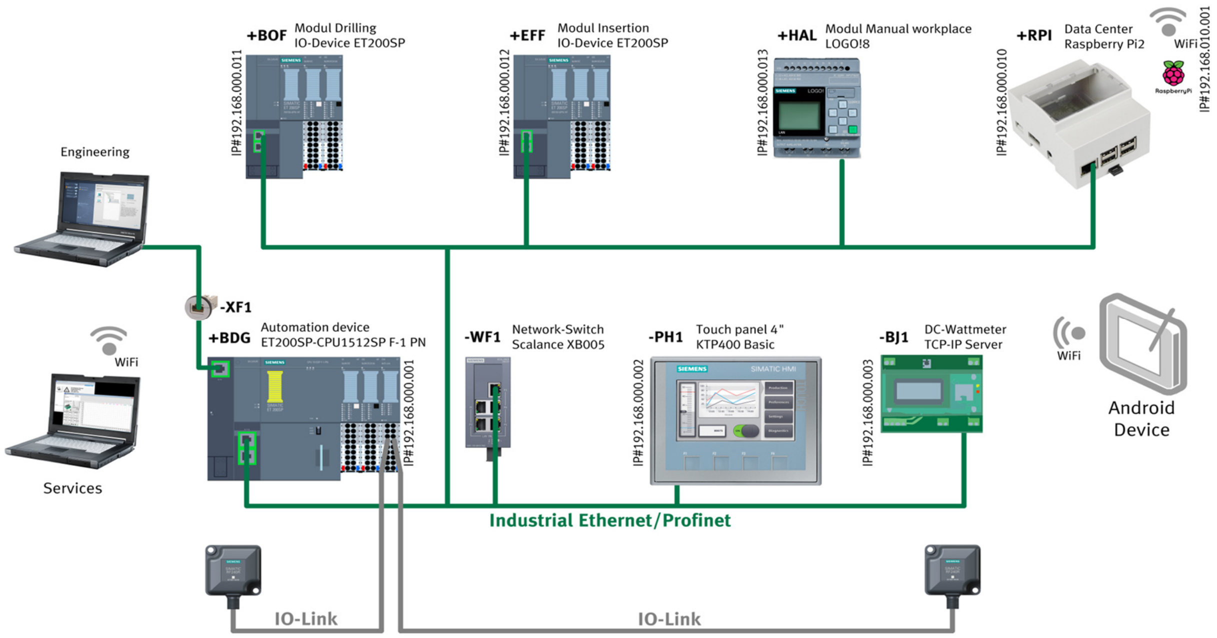


Figure 33: Architecture of the Compact Trainer.

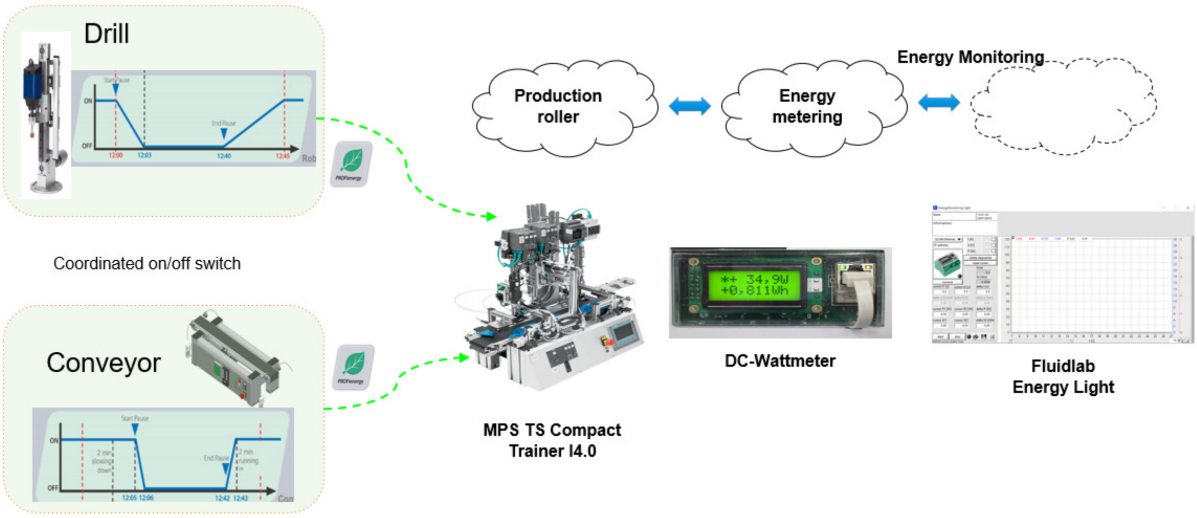


Figure 34: PROFIenergy scenario for the Compact Trainer.

5 Large scale demonstrators

5.1 ICAM large scale pilots

PP6 ICAM constructed a large scale demonstrator that has been used in several demonstration actions (Figure 35).
For more accurate power and energy consumption measurements, PP2 KU Leuven constructed the large scale pilot described in 5.2. This data has been used in the calculation tool (6 Calculation tool).

Figure 35: ICAM large scale demonstrator

5.2 Levitation setup at KU Leuven

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 36). 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 37 a and b.

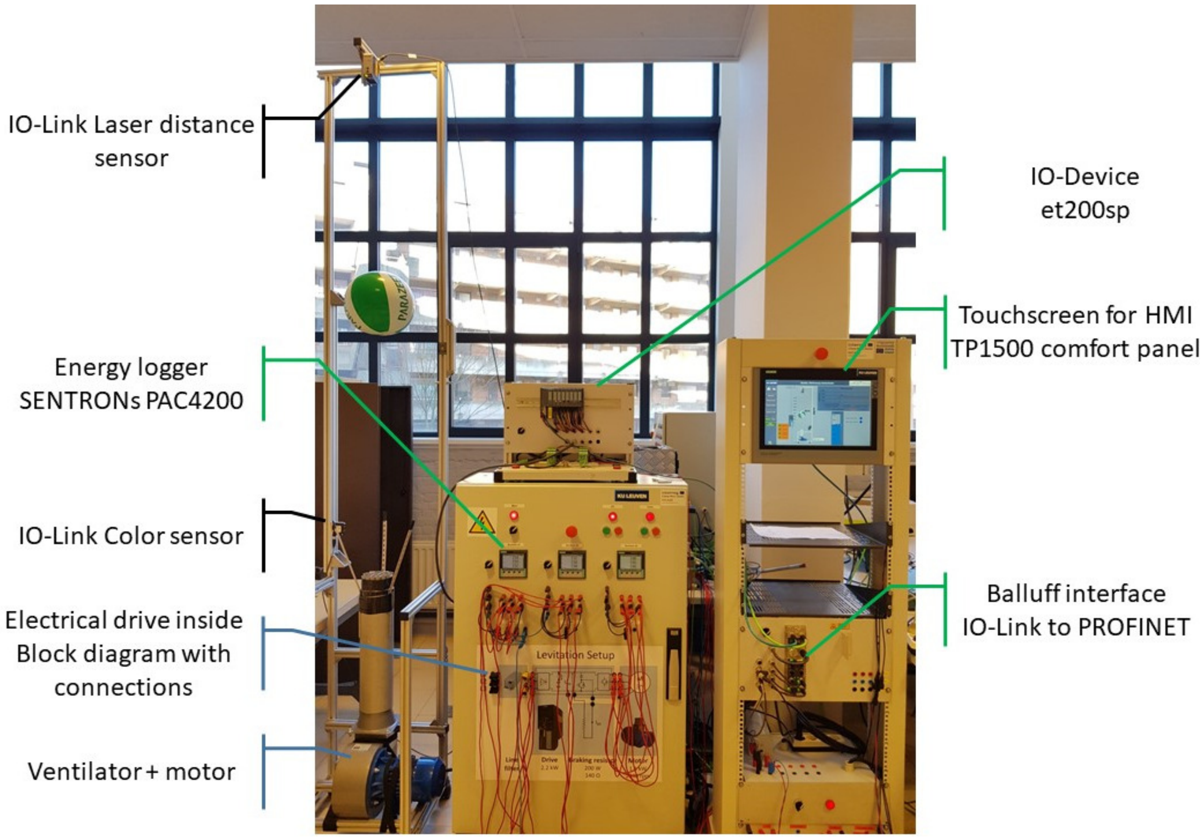


Figure 36: Levitation setup – green are PROFINET components, black are IO-Link components, blue indicates information..

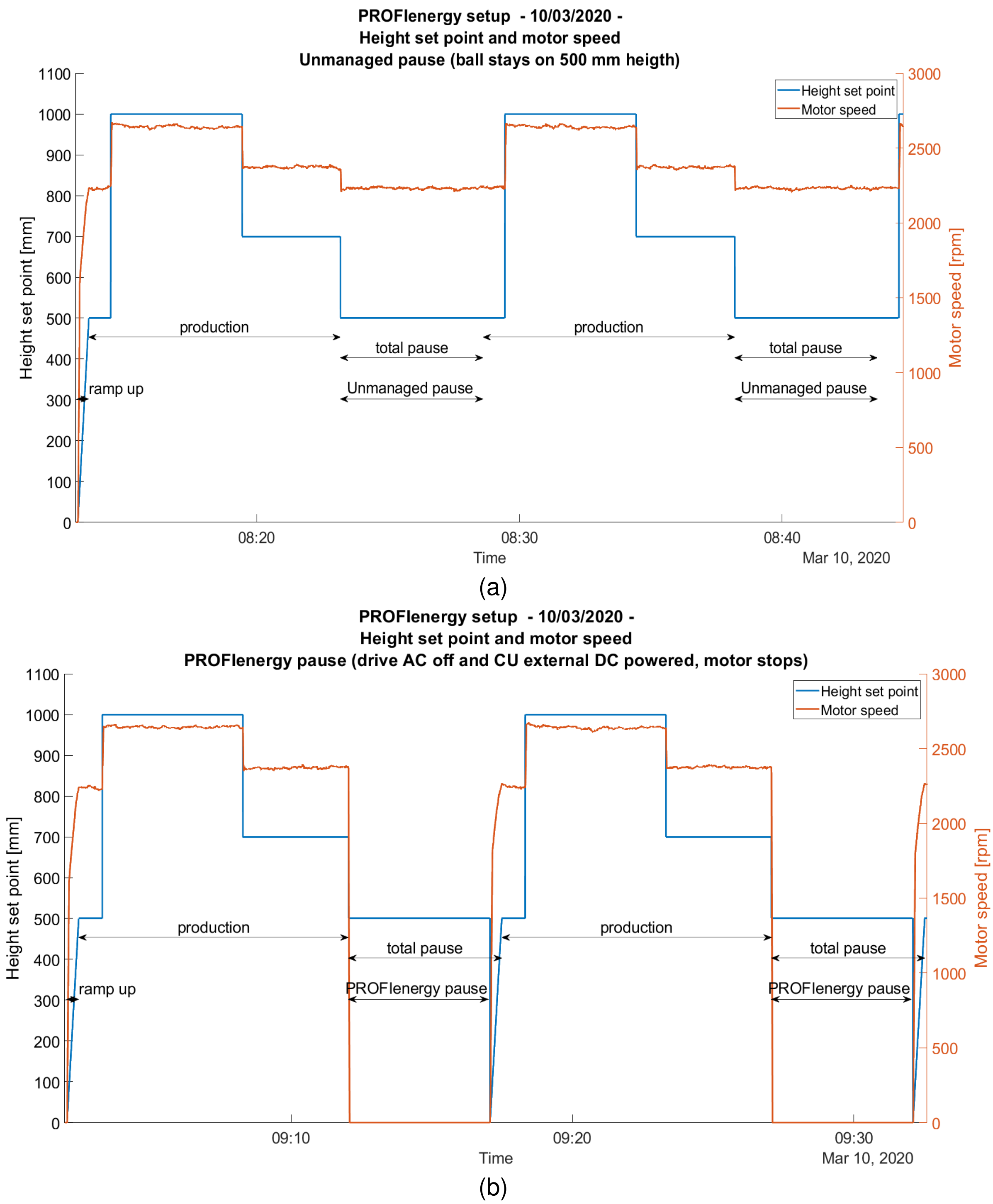


Figure 37: Demonstrator modes PROFIenergy and Unmanaged pause. (a) Unmanaged pause height set point and motor speed. (b) PROFIenergy pause height set point and motor speed.

5.2.1 Development of the levitation setup

5.2.1.1 Brief hardware description

The schematic overview can be found in Figure 38. The measurement points (indicated with circles) are measurement points on the enclosure door for voltage and current. Refer to Figure 39 for a typical connection during measurements. The numbers at the end of PROFINET component names are the last part of the PROFINET addresses.

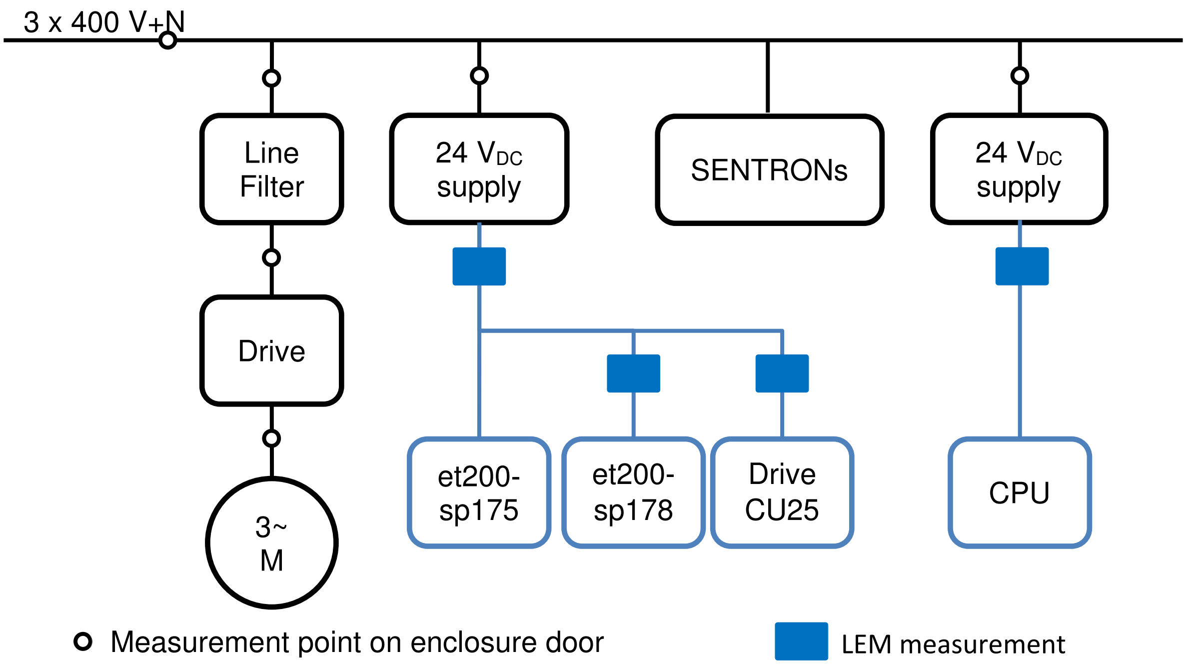


Figure 38: Schematic overview of the measurement points in the electric circuit.

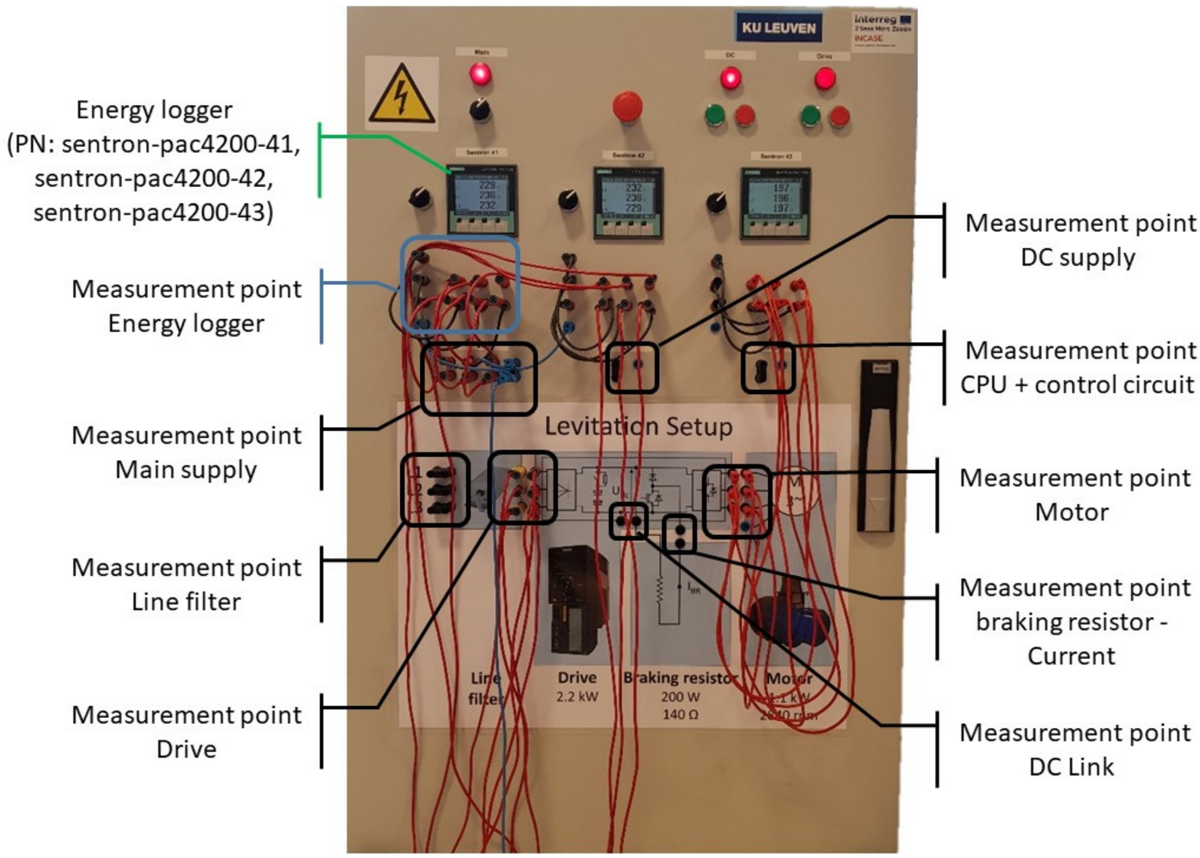


Figure 39: Door layout with at the top the SENTRONs and at the bottom the block diagram of the drive.

With the three SENTRONs mounted on the door (Figure 39, Figure 40) it is easy to measure on different points of the setup. Inside the enclosure are four LEM boards (Figure 41) 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 40: SENTRON PAC4200.

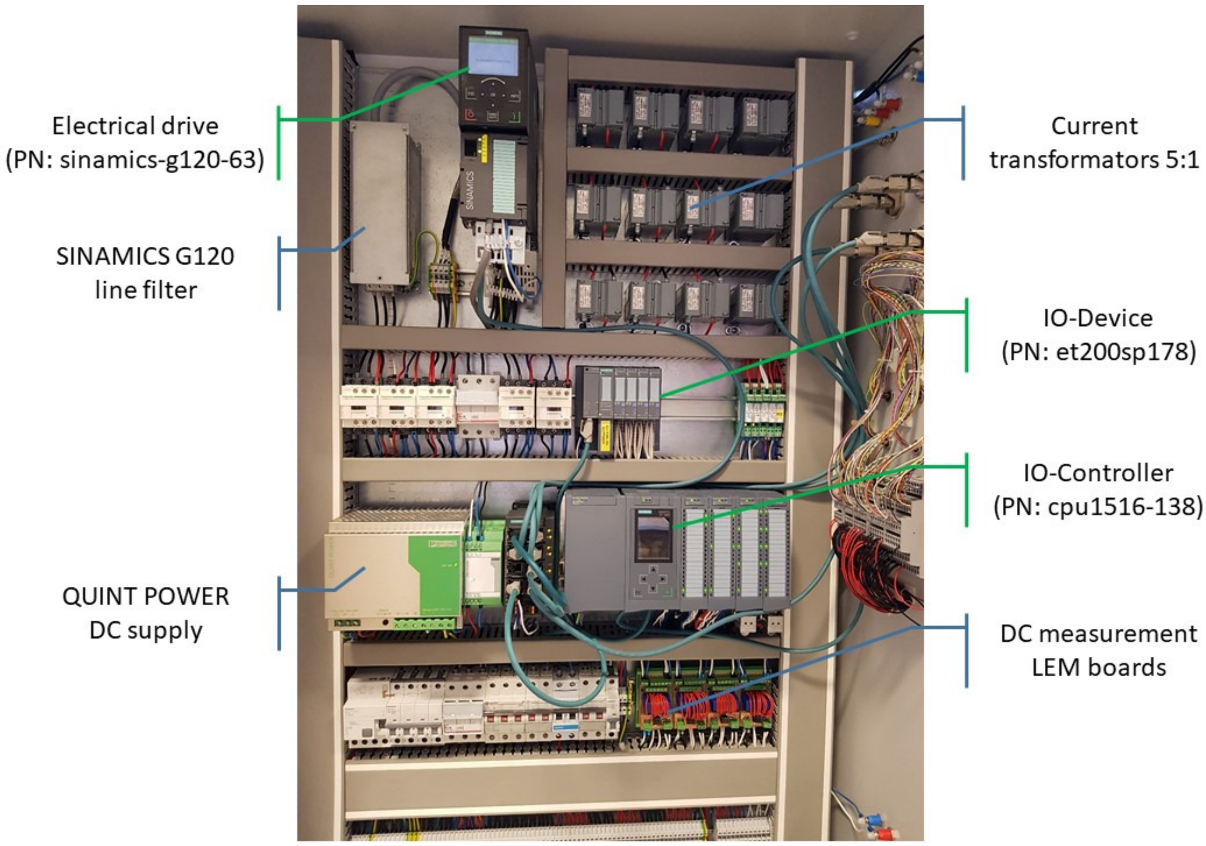


Figure 41: Detailed view inside the enclosure.

5.2.1.2 Brief network description

The PROFINET network overview can be found in Figure 42.

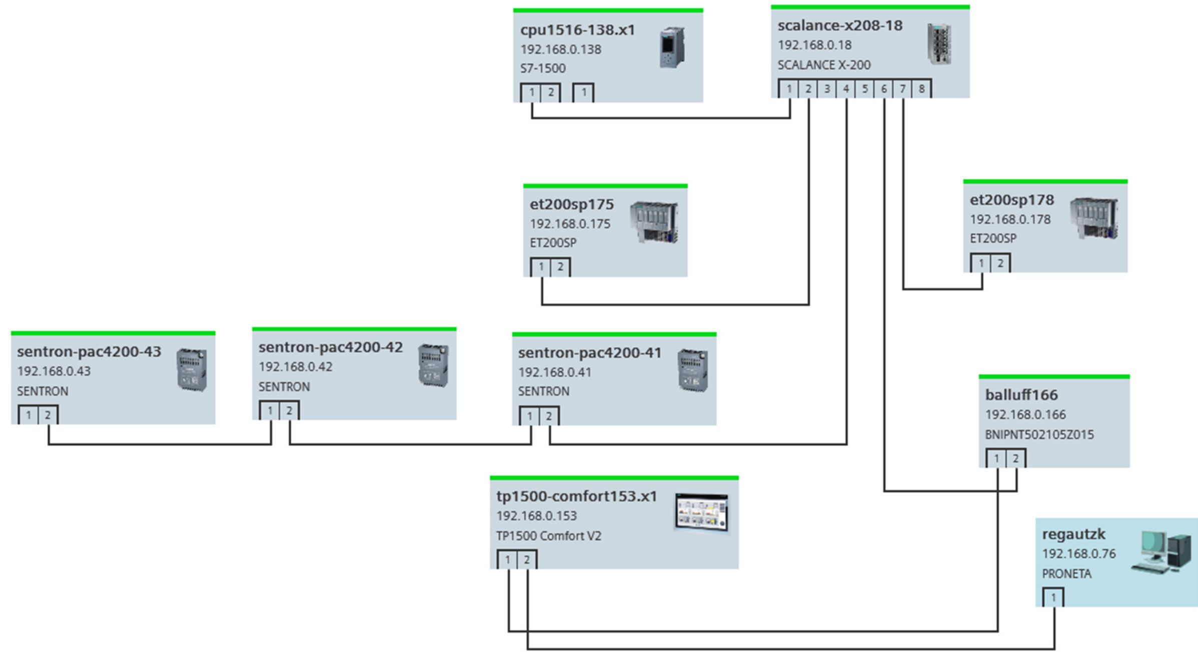


Figure 42: PE demonstrator levitation setup network overview.

An overview of the PROFINET devices can be found in Table 2 (Figure 42):

Table 2: 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 3:

Table 3: 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

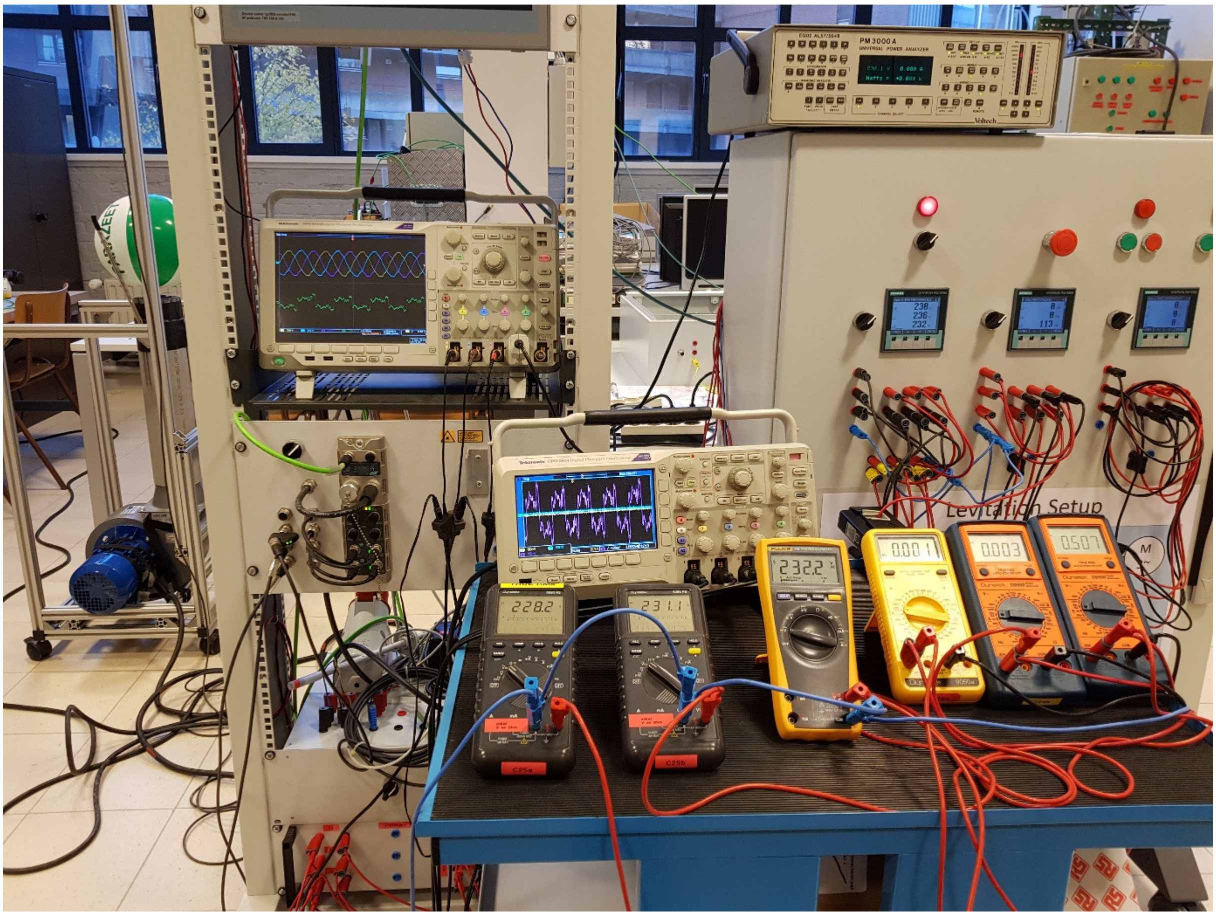


Figure 43: Typical use of measurement setup, with additional multimeters, oscilloscopes and (on top) high precision power analyzer.

During the commissioning and testing phase, additional measuring equipment was used for quick verifications, refer to Figure 43 for a typical measurement setup.

The software used in this demonstrator:

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

5.2.2 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 37, Figure 44 and Figure 45. 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.

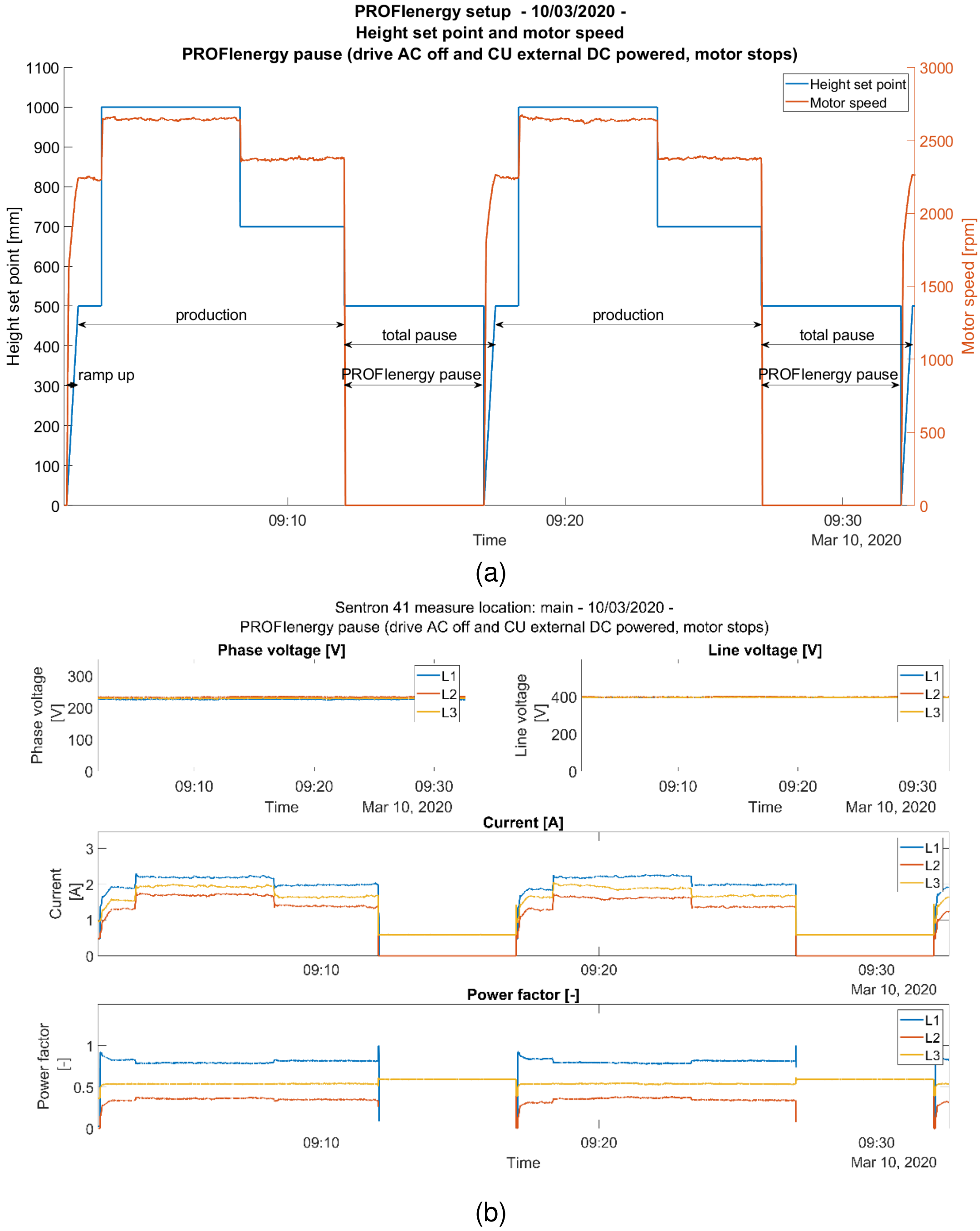


Figure 44: PROFIenergy plot (a) height set point and motor speed. (b) SENTRON 41 voltage, current and power factor measurement on the main supply of the enclosure.

The levitation sequence is explained in detail in Figure 45.

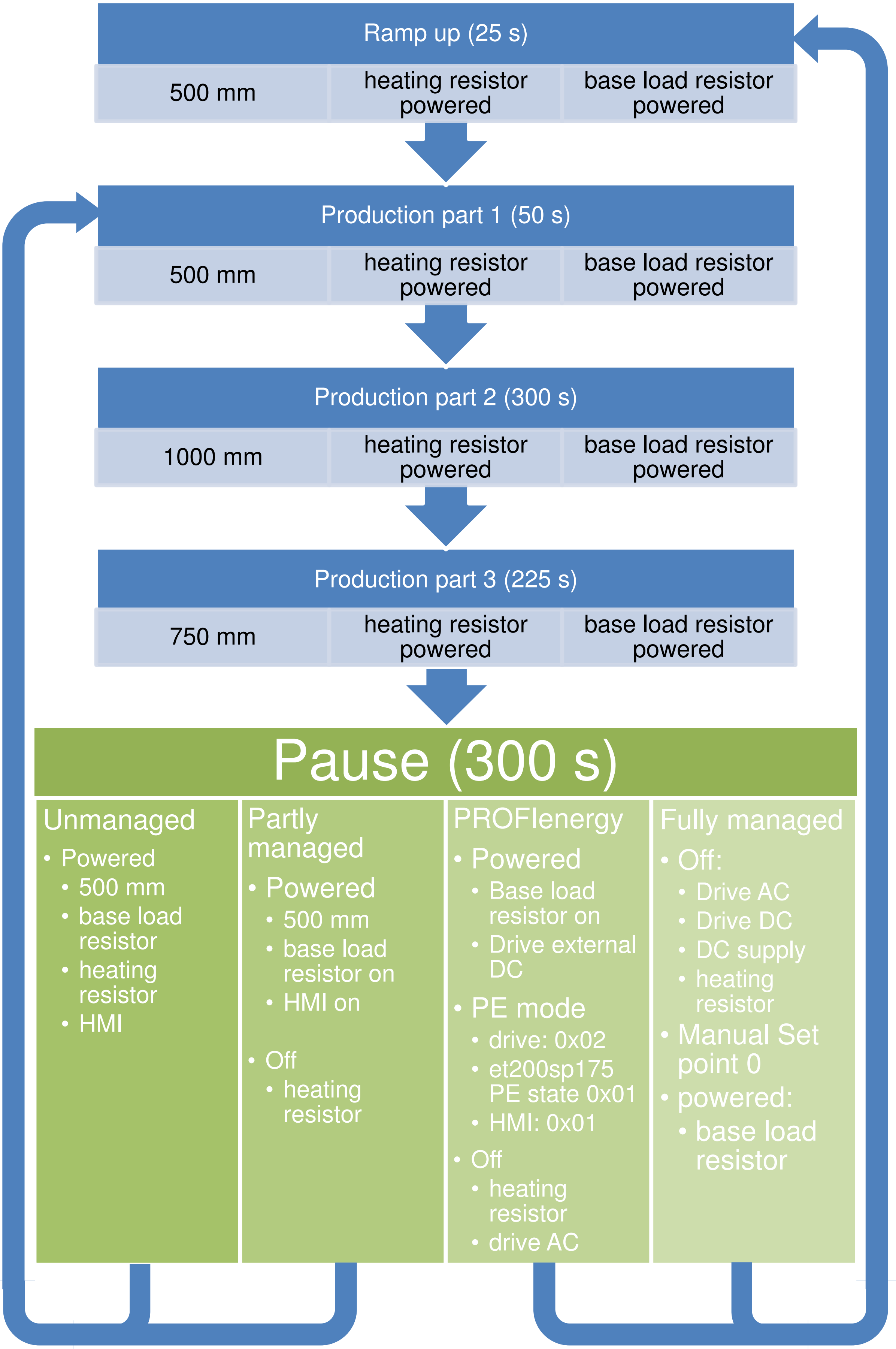


Figure 45: Demonstrator sequence.

5.2.2.1 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.

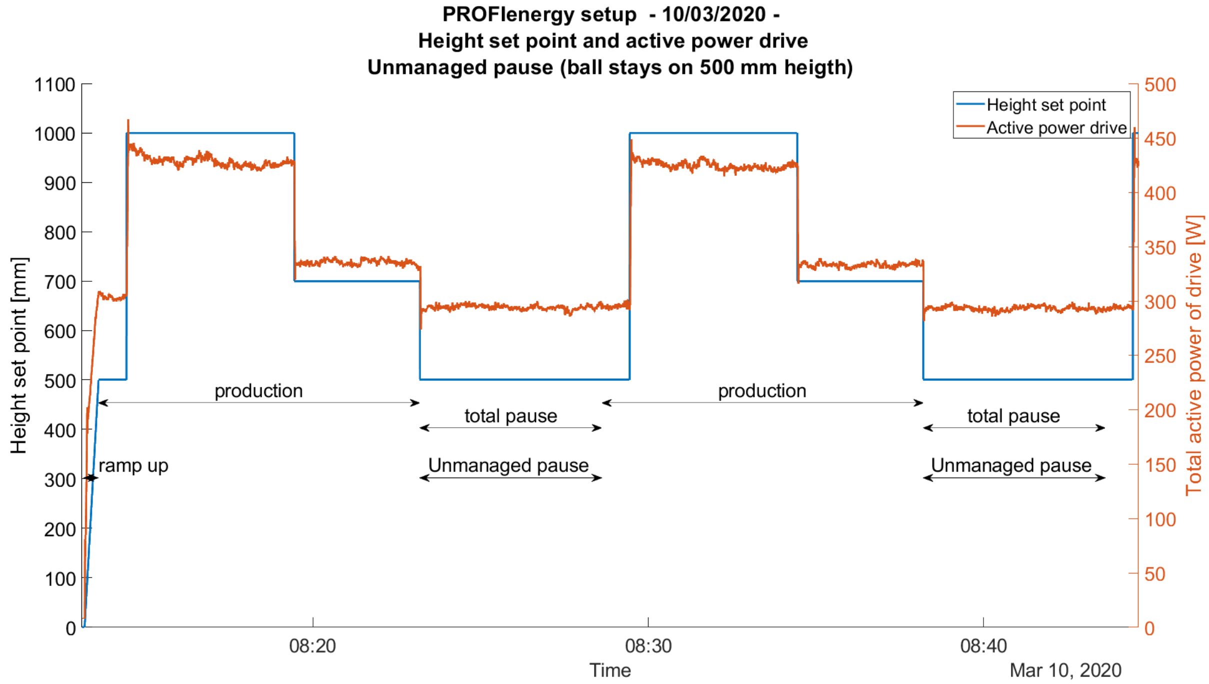


Figure 46: Cycle of an unmanaged pause (active power of the drive on the right).

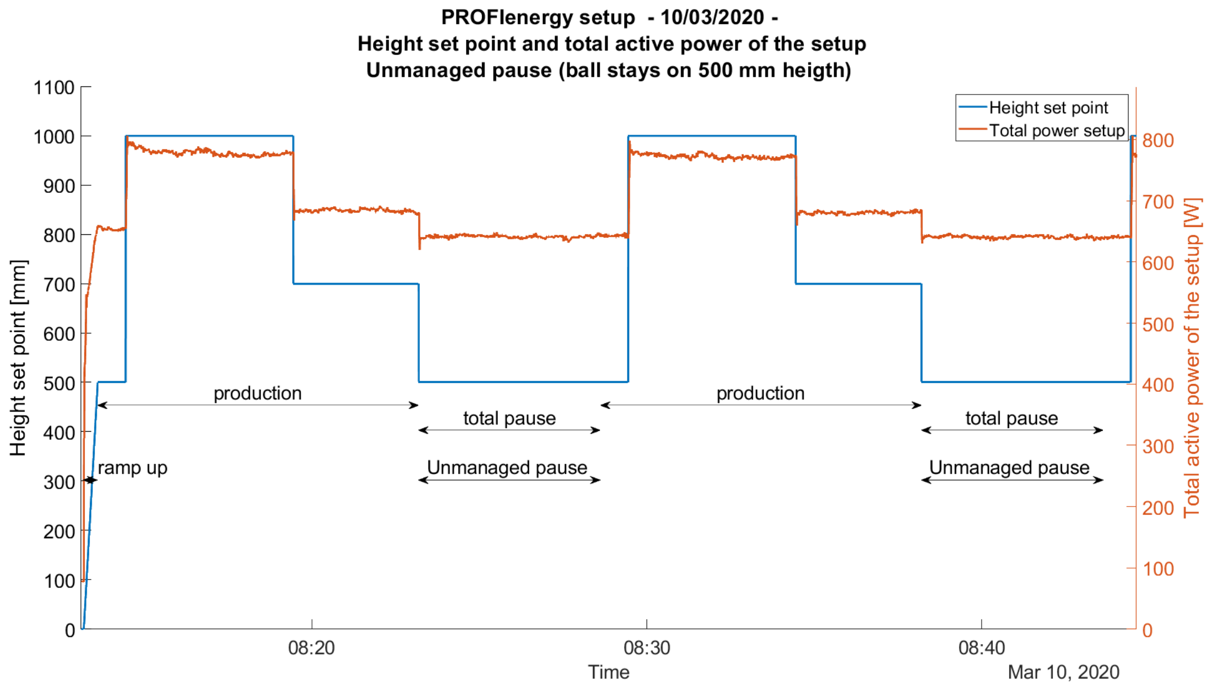


Figure 47: Cycle of an unmanaged pause (total active power of the setup on the right).

5.2.2.2 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 47) to 370 W (Figure 48). The drive power consumption is unchanged and is the same as in Figure 46.

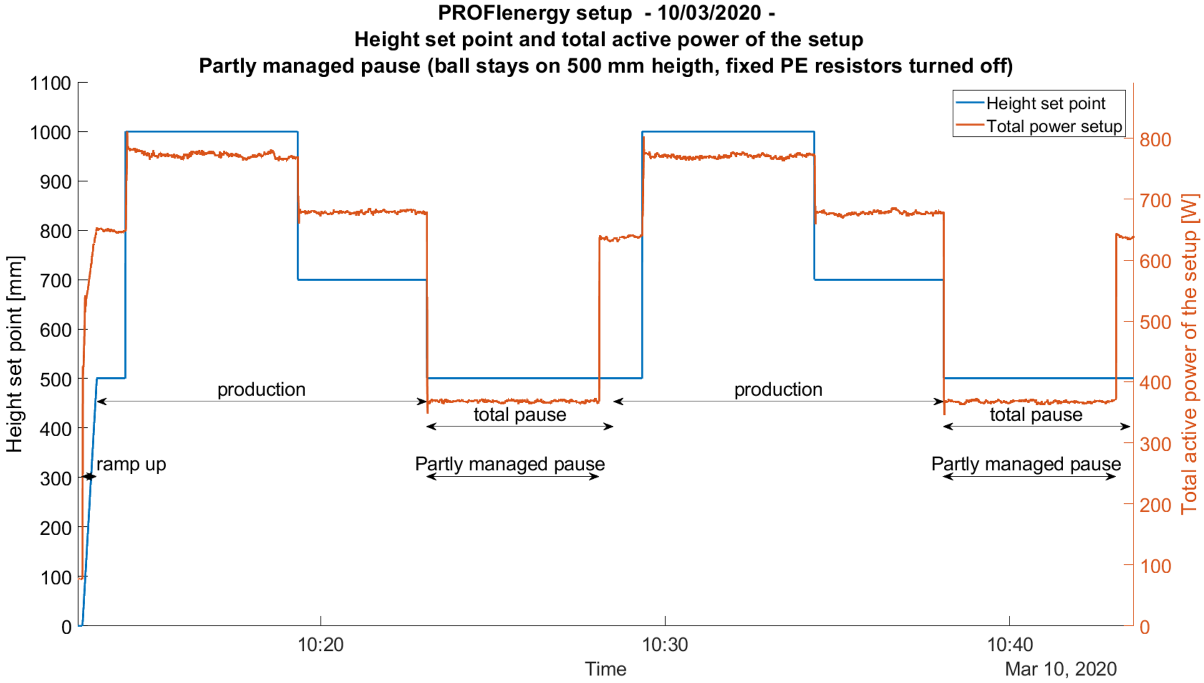


Figure 48: Cycle of partly managed pause (total active power of the setup on the right).

5.2.2.3 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 49).

The et200sp175, et200sp178 and the sinamics-g120-63 are not reachable in the PN network during the pause.

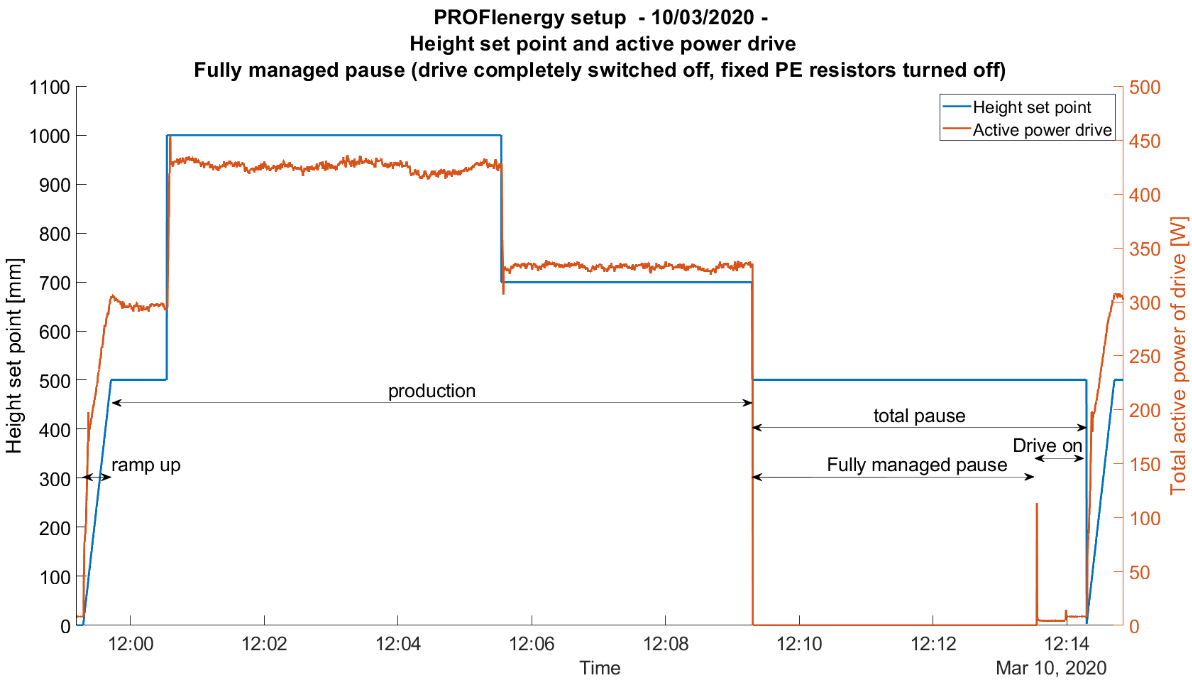


Figure 49: Cycle of the fully managed pause (total active power of the drive on the right).

5.2.2.4 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[3].
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 51) 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 50). All components are visible in the PN network.

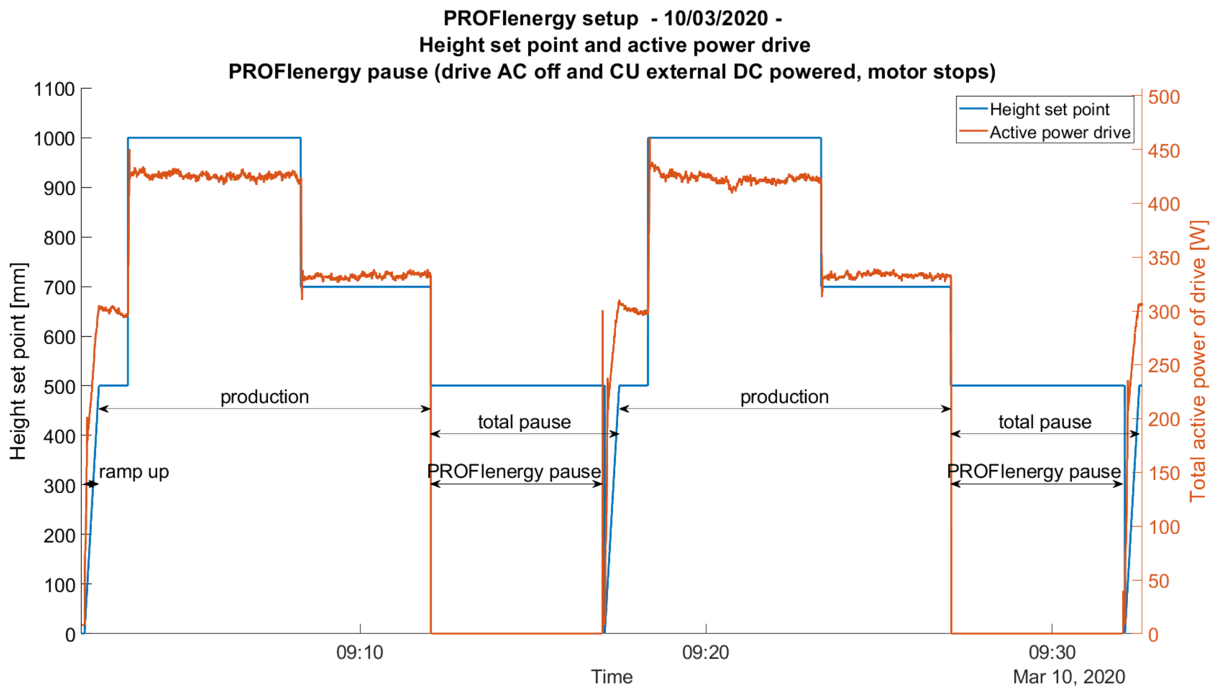


Figure 50: Cycle of PROFIenergy pause (total active power of the drive on the right).

[3] 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.

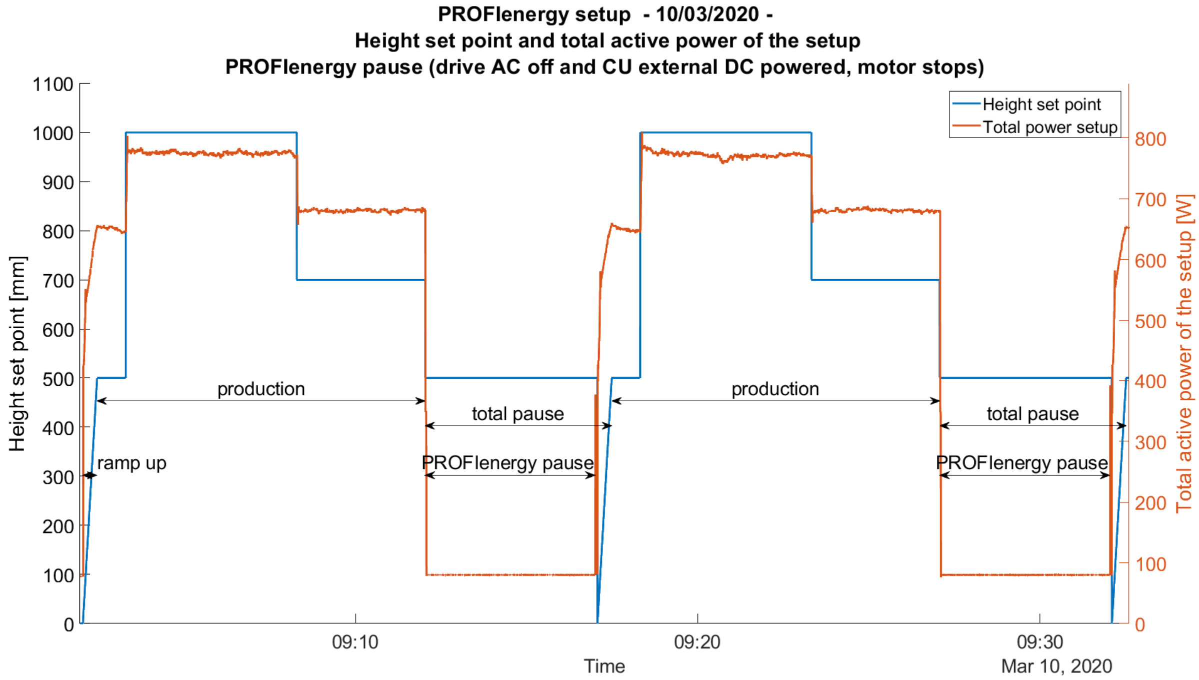


Figure 51: Cycle of PROFIenergy pause (total active power of the setup on the right).

5.2.3 Visualization

Figure 52 shows the control screen of the levitation. A trend view shows the set point and the instant and average ball levitation.

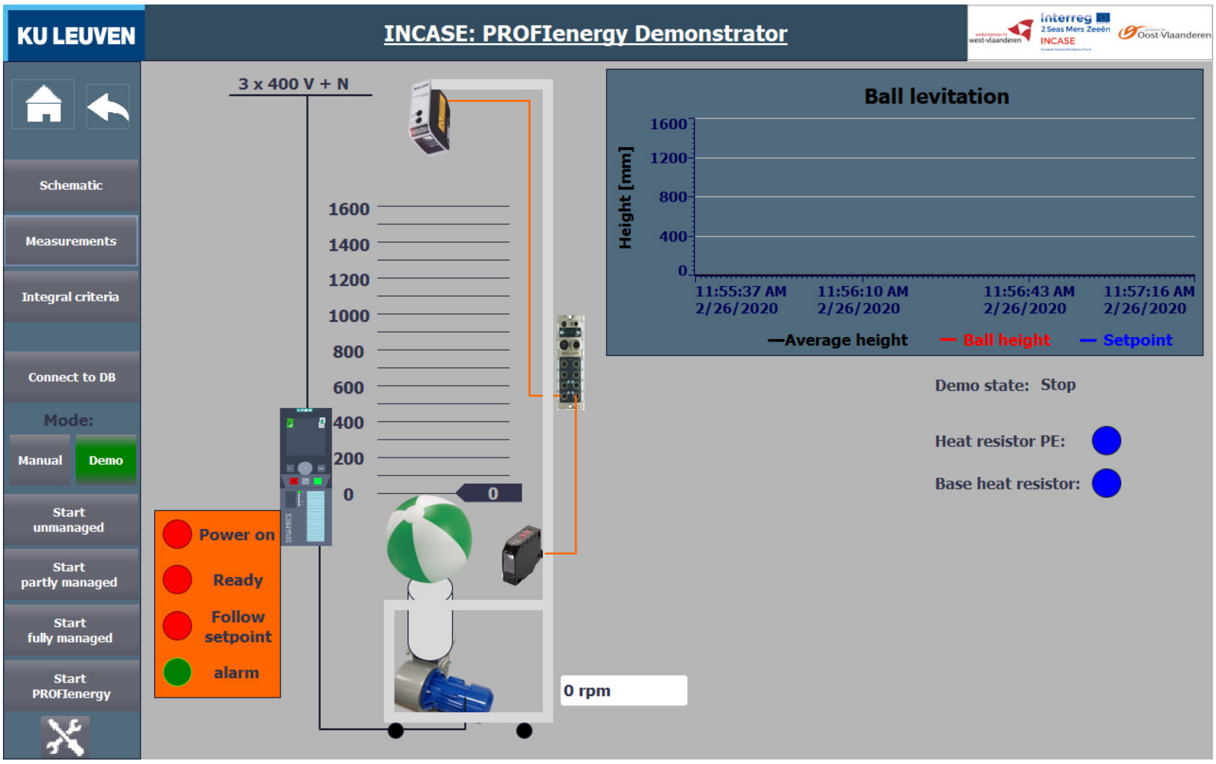


Figure 52: Control screen of the levitation setup.

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 53) 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 54). With the “Get info” button the query measurement value information is shown in a window at the bottom of the screen.

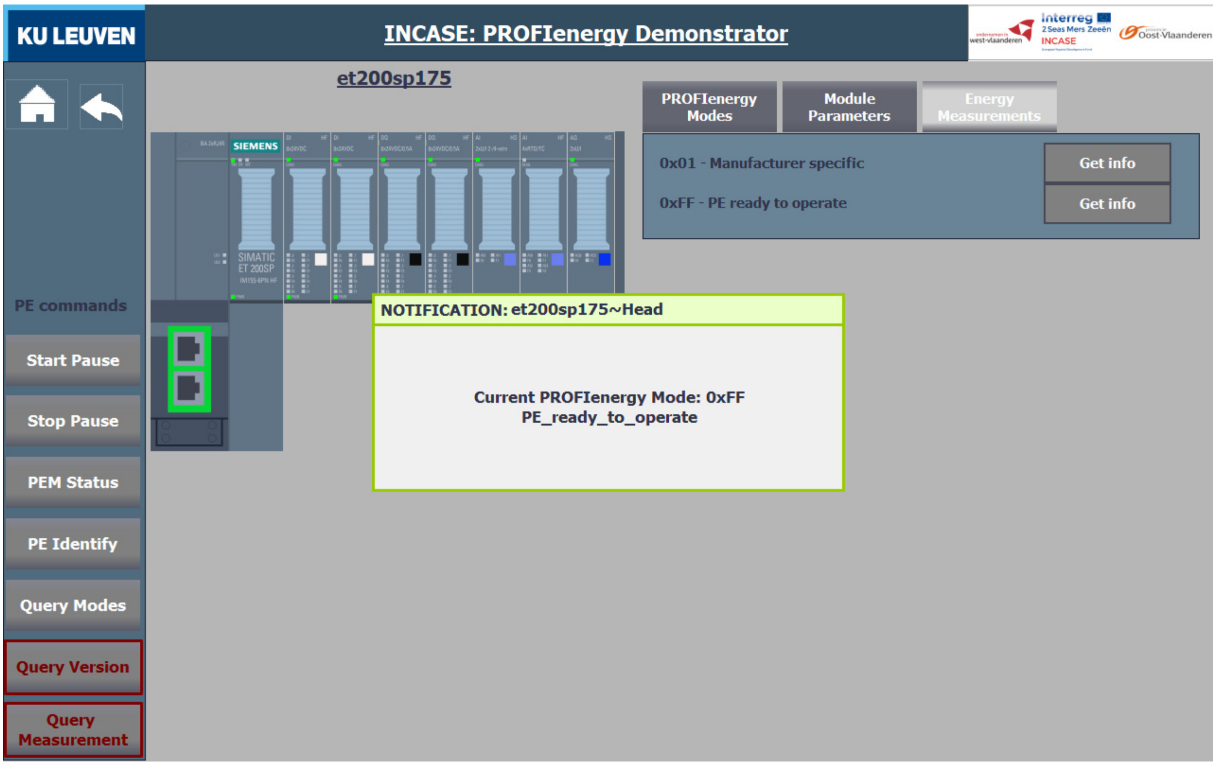


Figure 53: PEM status of et200sp175.

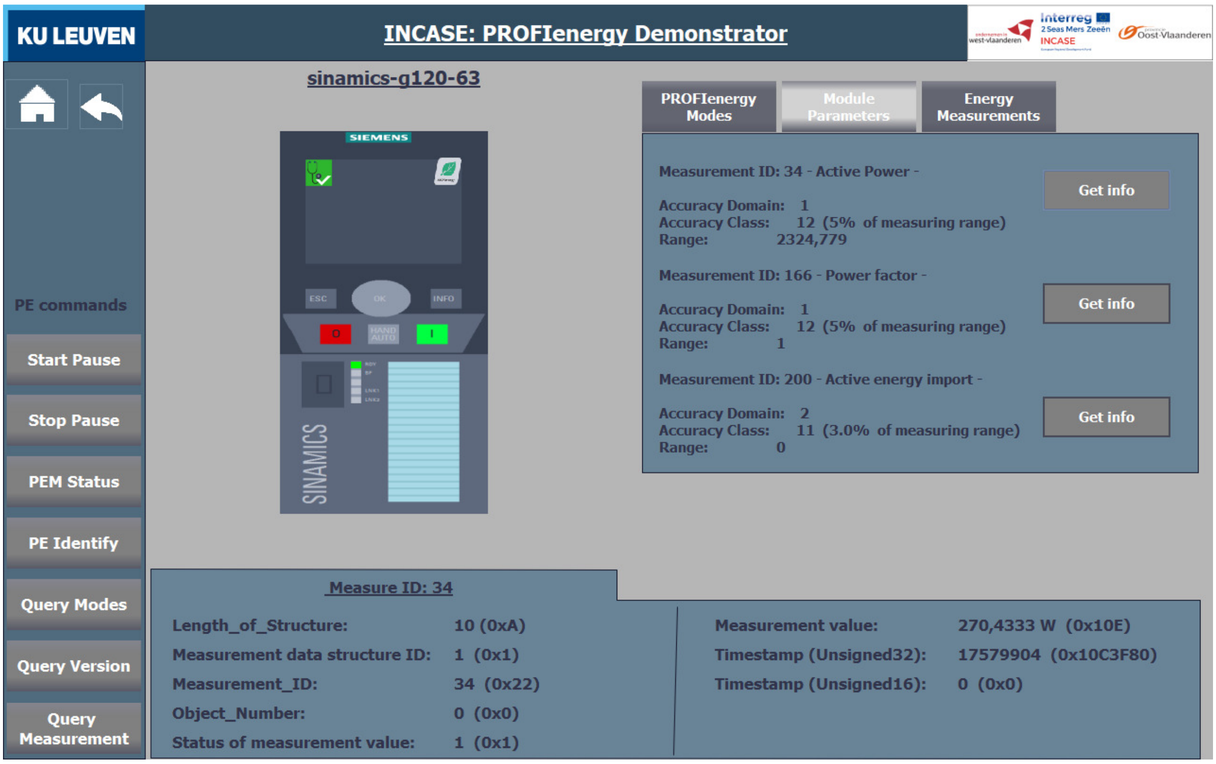


Figure 54: Query measurement list and value of the sinamics-g120-63. [13]

5.2.4 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 [9] [14] [15] [10].

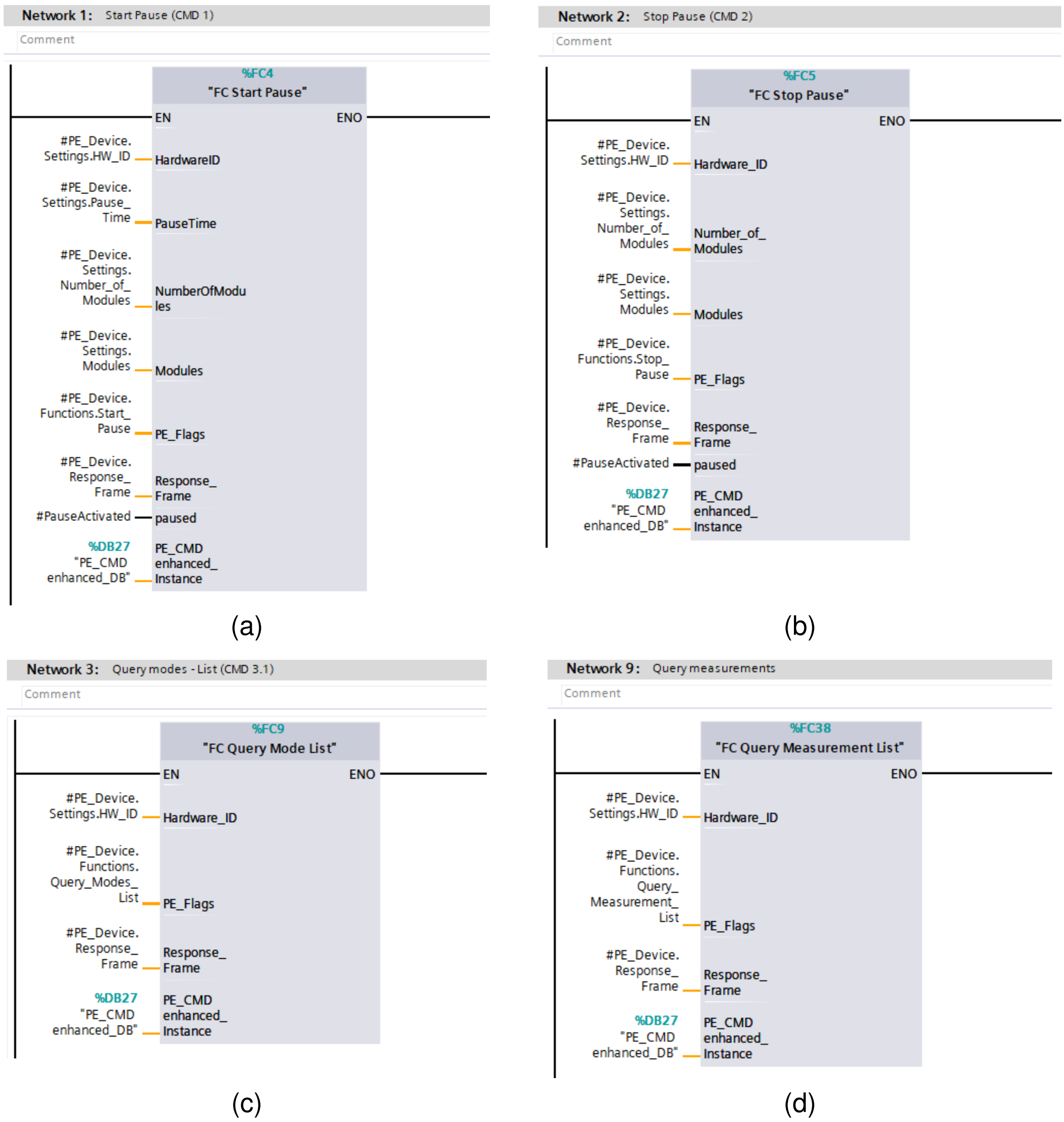


Figure 55: PROFIenergy functions in TIA Portal.

5.2.5 Results

These measurements are done with the Voltech PM3000a[4]. Refer to Figure 43 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. [16]

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

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.

5.2.5.1 Main supply measurement

Table 4: 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

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

5.2.5.2 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 5: 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 6 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 6: 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**

5.2.5.3 PLC and contactor circuits measurement

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

5.2.5.4 et200sp measurement

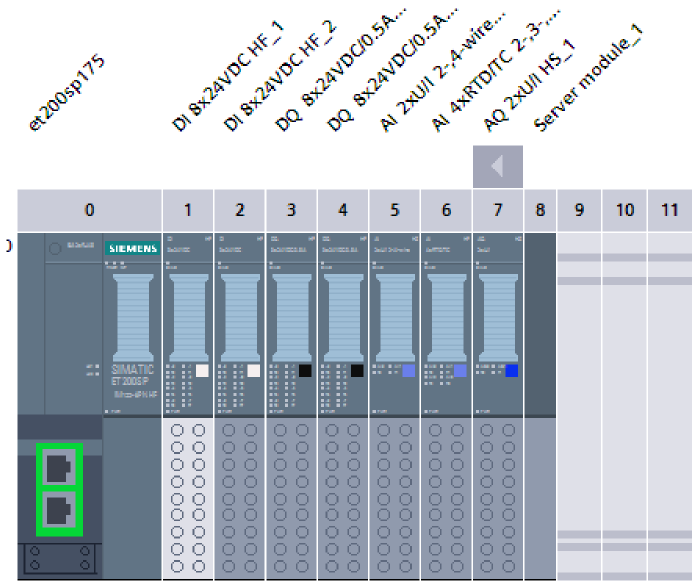


Figure 56: et200sp configuration.

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 et200sp "ready to operate" and energy saving mode 0x01.

	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

5.2.5.5 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***

5.2.5.6 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[5].

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

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

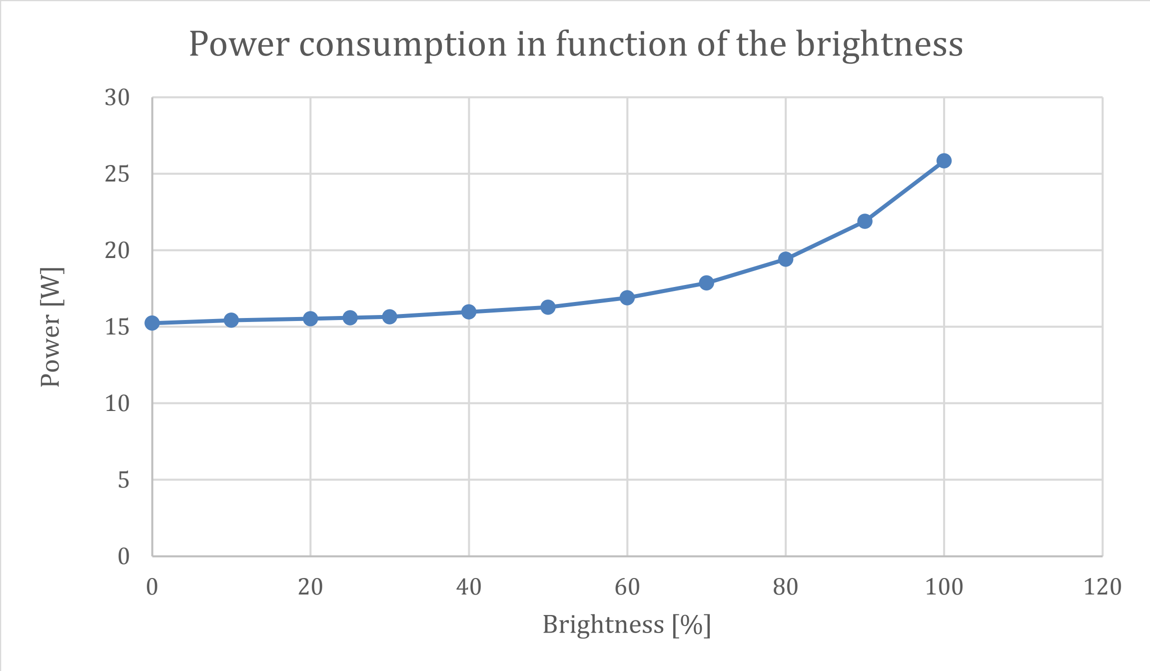


Figure 57: Power consumption of a TP1500 comfort panel in function of the brightness

6 Calculation tool

6.1 Introduction and assumptions

The idea of the calculation tool is to measure individual components with high accuracy, combine with pauses and calculate the energy saving potential for a larger industrial production line.
There are 3 use cases defined with observer partners Volvo Cars Gent and Siemens: a production cell, a conveyor belt and an overhead conveyor belt.

The first version of the calculation tool was programmed using Microsoft Excel. The tool was later converted into a C# program using Microsoft Visual Studio 2017 (Version 15.9.20).

In its final version, the tool can be used to estimate the energy saving potential in a production cell or line. As follow-up of the INCASE project, Volvo Cars (Ghent and Sweden), Siemens and KU Leuven are extending the measurements with among others large ABB industrial robots, and applications in the large industrial use cases.

Some basic assumptions listed underneath.

- Resolution pauses is in minutes.
- Devices can be:
  - In Operate mode (full production)
  - In PE_ready_to_operate mode (under voltage)
  - In PE mode(s)
  - In PE_power_off
  - Running idle.
- Multiple energy prices can be used to calculate the total energy cost:
  - Daytime price during weekdays
  - Nightly price during weekdays
  - Daytime price during weekends
  - Nightly price during weekends
- The start time of each period can also be changed.

6.2 Description of the calculation tool

The application consists of two large panels, the panel on the left contains the menu and the panel on the right displays the content selected in the menu.

Figure 58: Main screen

6.2.1 Library

The first option in the menu is "Library", this displays the list of devices in the library that can be used in the calculations (Figure 59). On start-up, the default library is loaded, but the users can create, save and open custom libraries.

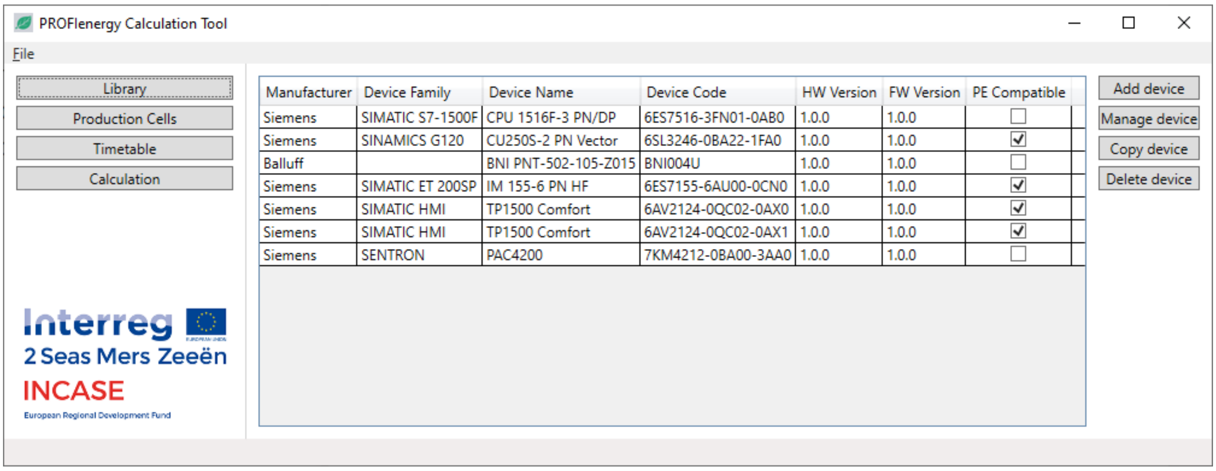


Figure 59: Library view

While adding or modifying a device, the view in Figure 60 is shown. The user can add or modify the details and energy consumption modes for the selected device.

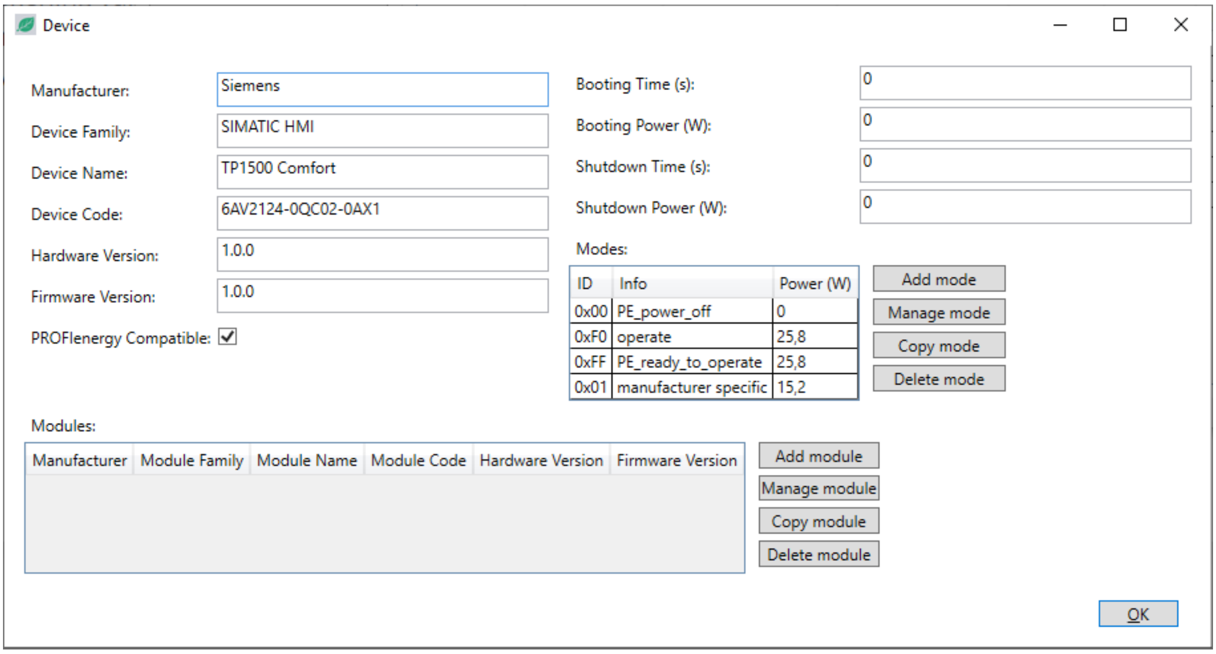


Figure 60: Library device details

6.2.2 Production cells

The second option in the menu is "Production Cells" (Figure 61), this displays the list of production cells for which the energy consumption should be calculated. By default, this list of production cells is empty. The buttons on the right can be used to add, manage, copy or delete production cells. The user can create, save and open this list of production cells.

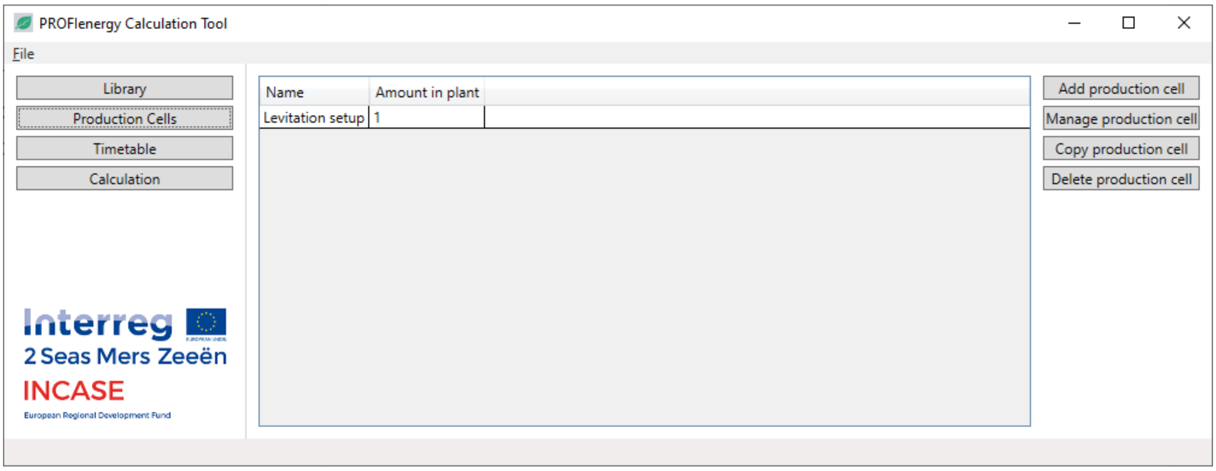


Figure 61: Productions cells view

While creating or modifying a production cell, the view in Figure 62 is shown. The user can add devices from the library and modify or delete the devices in the production cell.

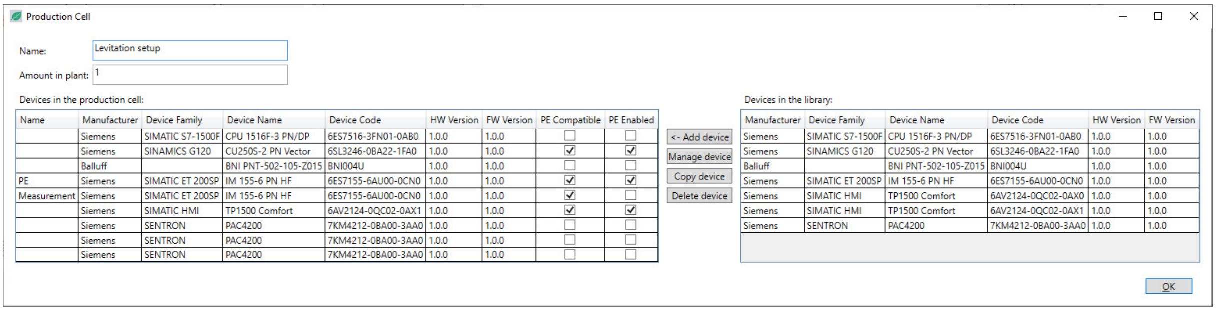


Figure 62: Production cell details

Most details for a device in a production cell are locked, except for:

- the name of the device
- whether or not PROFIenergy is enabled (in case the device is PROFIenergy compatible)
- the connected modules (in case of a device with modules)

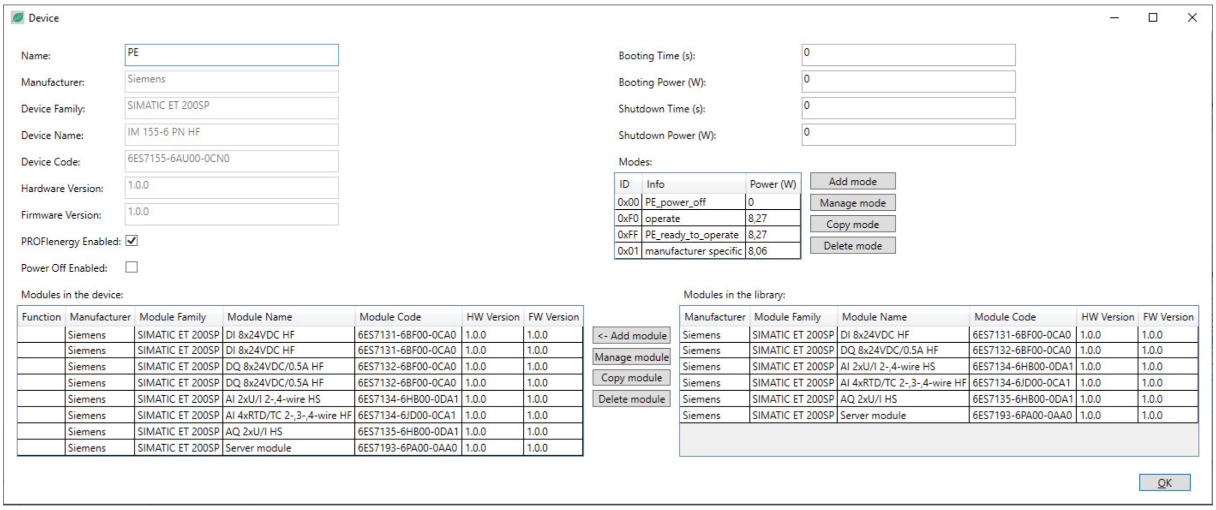


Figure 63: Device details in a production cell

The connected modules can be added, modified or removed, similarly to the devices in the production cell. For each module, connected loads can be specified with the option to make them switch off during a PROFIenergy mode.

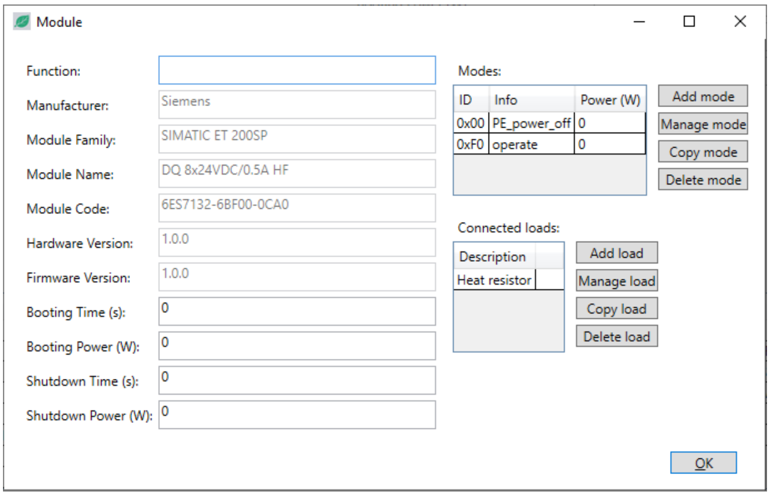
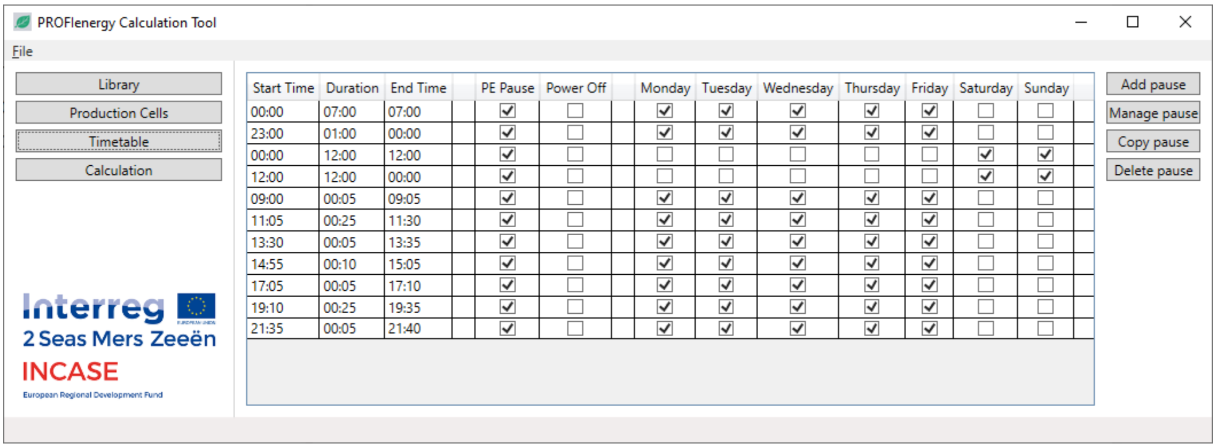


Figure 64: Module details in a device in a production cell

6.2.3 Timetable

The third option in the menu is “Timetable”, this displays a list of pauses. By default, the list of pauses is empty. The buttons on the right can be used to add, manage, copy and delete pauses. Just like the library and production cells, the user can create, save and open this list of pauses.



Start Time	Duration	End Time	PE Pause	Power Off	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
00:00	07:00	07:00	☑	☐	☑	☑	☑	☑	☑	☐	☐
23:00	01:00	00:00	☑	☐	☑	☑	☑	☑	☑	☐	☐
00:00	12:00	12:00	☑	☐	☐	☐	☐	☐	☐	☑	☑
12:00	12:00	00:00	☑	☐	☐	☐	☐	☐	☐	☑	☑
09:00	00:05	09:05	☑	☐	☑	☑	☑	☑	☑	☐	☐
11:05	00:25	11:30	☑	☐	☑	☑	☑	☑	☑	☐	☐
13:30	00:05	13:35	☑	☐	☑	☑	☑	☑	☑	☐	☐
14:55	00:10	15:05	☑	☐	☑	☑	☑	☑	☑	☐	☐
17:05	00:05	17:10	☑	☐	☑	☑	☑	☑	☑	☐	☐
19:10	00:25	19:35	☑	☐	☑	☑	☑	☑	☑	☐	☐
21:35	00:05	21:40	☑	☐	☑	☑	☑	☑	☑	☐	☐

Figure 65: Timetable view

The view in Figure 66 is used to add or modify pauses. The user can specify the start time and the end time or duration. There is also a checkbox to indicate whether or not this pause is a PROFIenergy pause. The next checkbox is to indicate whether or not this pause is a power off pause, this means that the devices that are power off enabled, will be powered off completely during this pause. Lastly, the user can select on which days of the week this pause occurs.

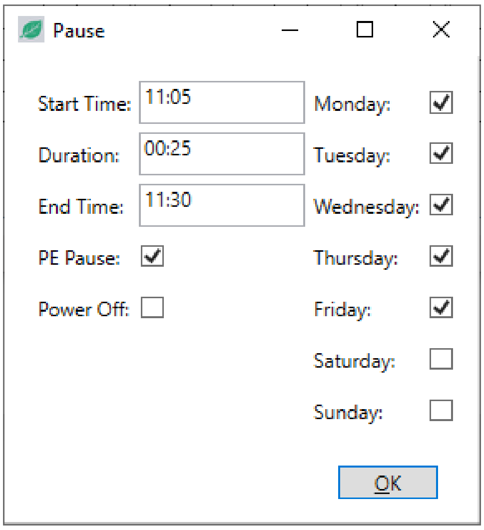


Figure 66: Pause details

6.2.4 Calculation

The fourth and last option in the menu is "Calculation", this displays the calculation page on which the energy saving potential is calculated. The user can modify the energy prices for week or weekend and day or night, the times when the day and night start can also be changed. There is also an option to ignore pauses shorter than or equal to a specific duration. The results are calculated on a weekly and yearly basis. The energy consumption is displayed for normal and PROFIenergy operation, both in kWh and €. The savings are also calculated in kWh, €[6] and % to give a clear overview of the energy saving potential.

The energy prices used are taken from a private (household) supplier contract and are just for indicatory purposes.

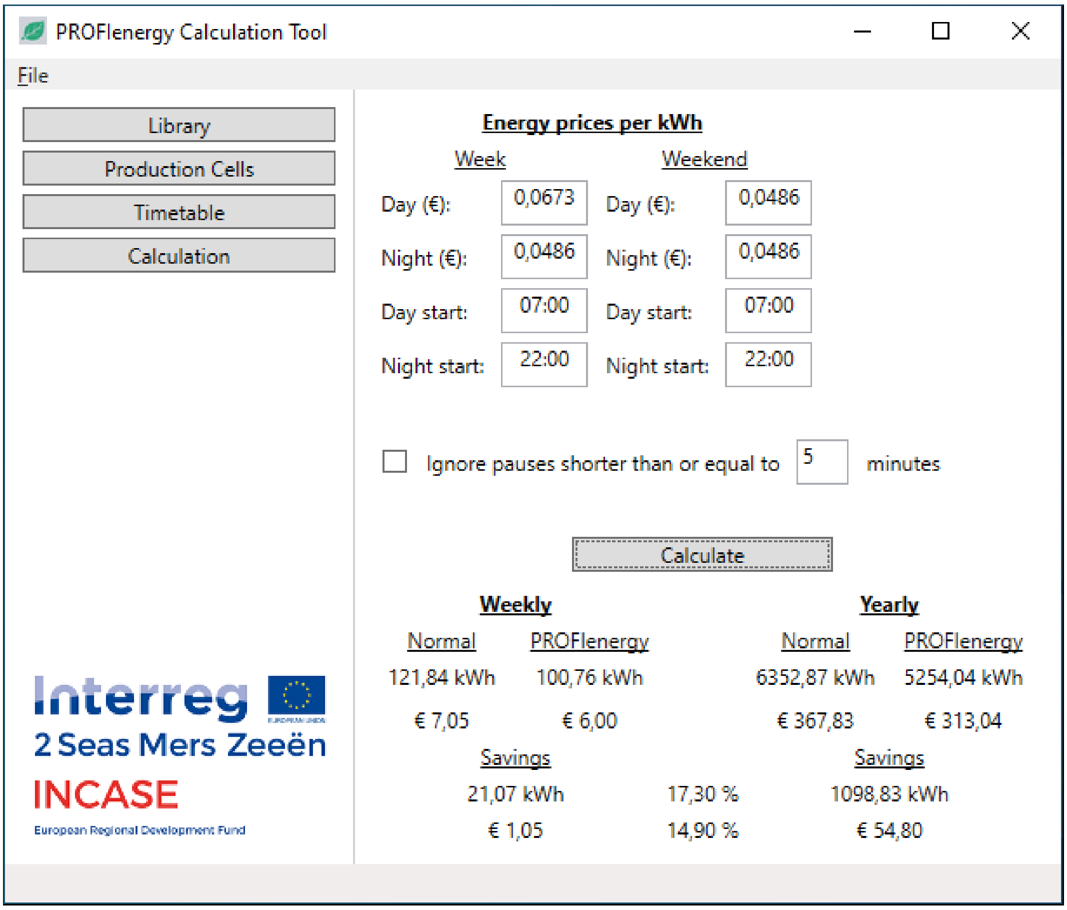


Figure 67: Calculation view

[6] In the current version of the calculation tool, the daytime price for weekdays is used for the calculation of the price during all ramp ups/downs, this results in an insignificantly small error in the total price. The total energy consumption is not affected by this calculation error.

7 Measurements and calculations

Note: the energy prices used are taken from a private (household) energy supplier contract and are merely for indicatory purposes.

7.1 Calculation tool example with Siemens TP1500 (PROFIenergy, 2 shift system)

For this example, a comparison is made for one Siemens TP1500 Comfort touch panel for HMI with product code 6AV2124-0QC02-0AX1 (most recent version). The details and energy consumption modes for this device can be found in Figure 68 (please refer to chapter 5 for the measurements).

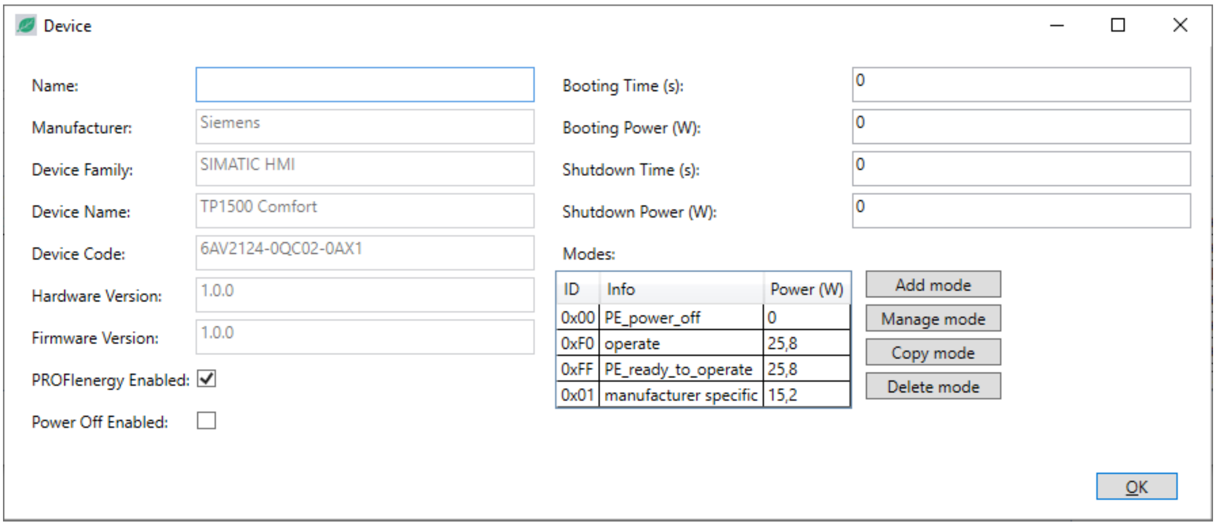


Figure 68: Siemens TP1500 details and energy consumption modes.

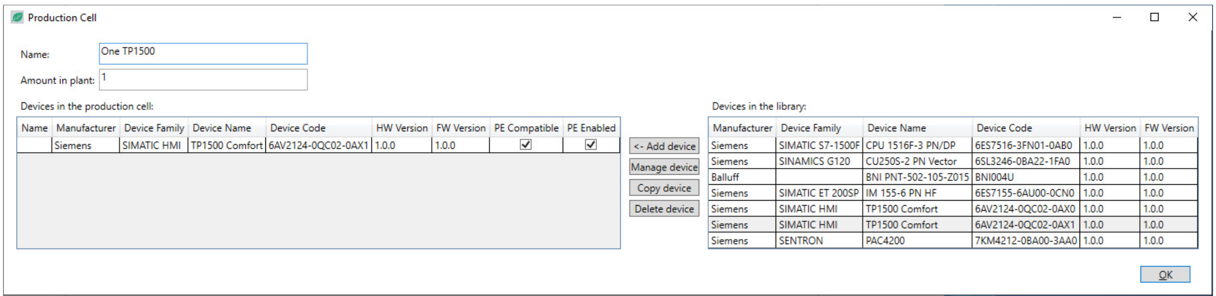


Figure 69: Production cell with one TP1500.

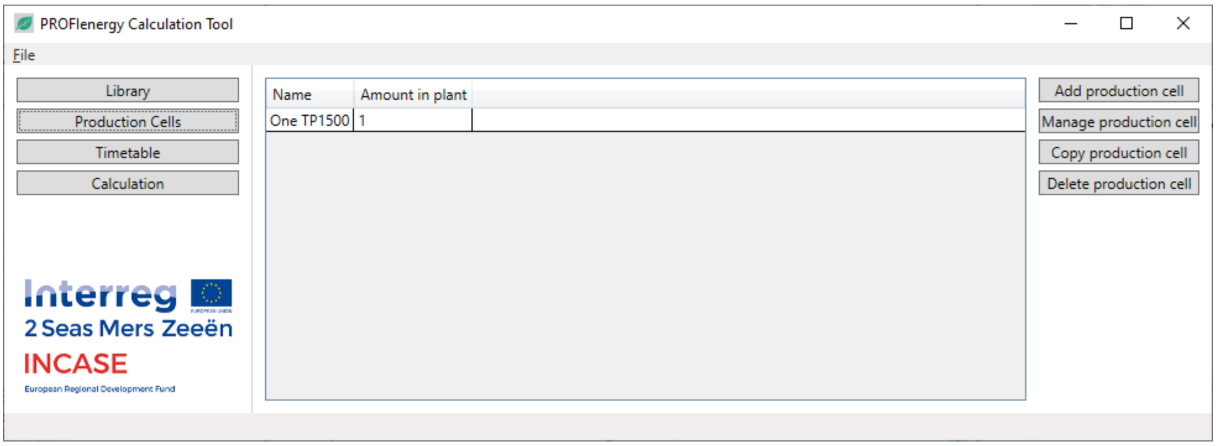


Figure 70: List of production cells with one production cell

For the timetable we assume a two shift system, no work in the weekend.

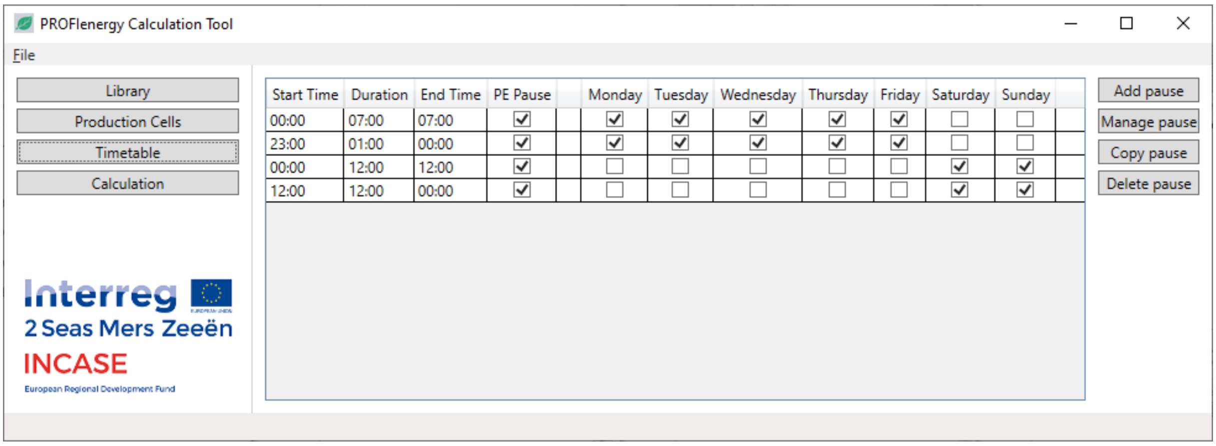


Figure 71: Timetable for two shifts per day, no work in the weekend.

The results of this calculation can be found in Figure 72.

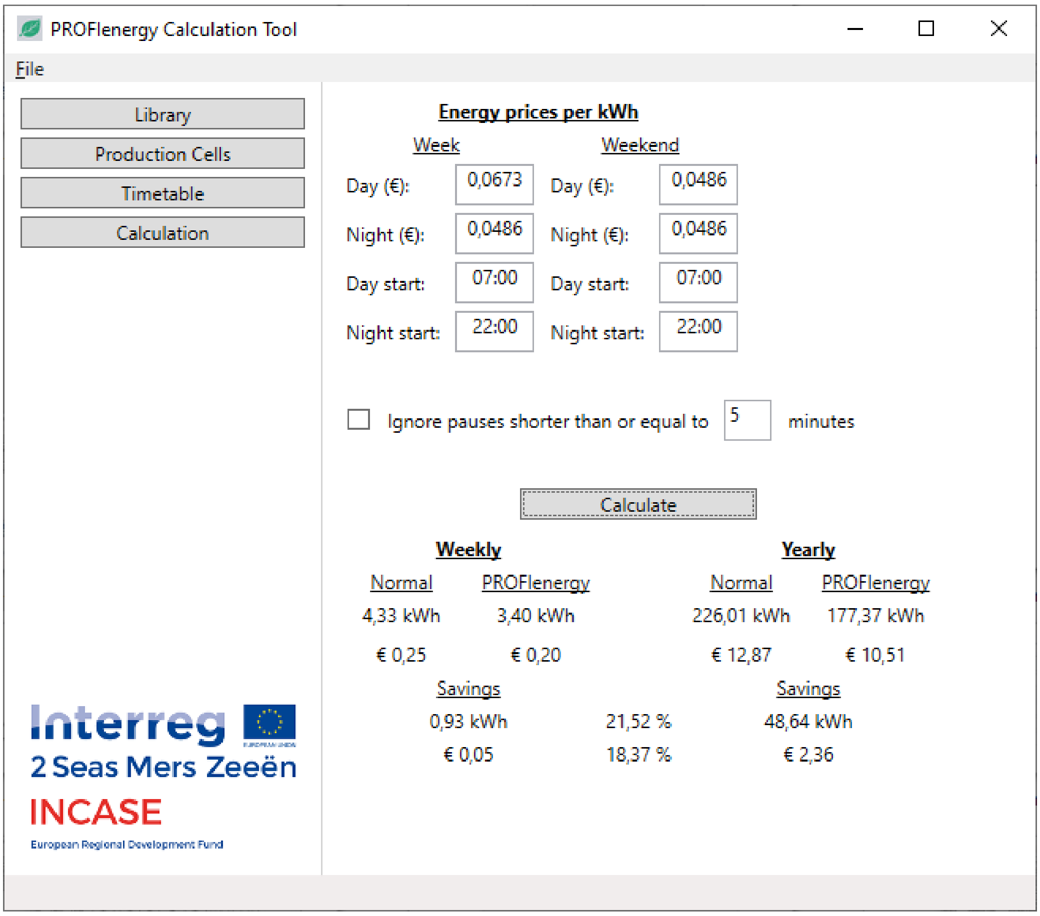


Figure 72: Calculation result for one TP1500 in a two shifts system with PROFIenergy.

7.2 Calculation tool example with Siemens TP1500 (new Volvo standard)

At Volvo Cars Gent, they realized that the touch panels are barely used (mainly during diagnostics and locating errors). That's why they implemented a system where the touch panels are always off, unless they are touched. So in this example, PROFIenergy is not used, but this system is a direct result of the cooperation between Volvo Cars Gent and KU Leuven during the INCASE project. This system is now adapted in the new Volvo Cars standard worldwide.

Figure 73 shows the calculation for one TP1500 with an estimate of 1 hour screen time per week.

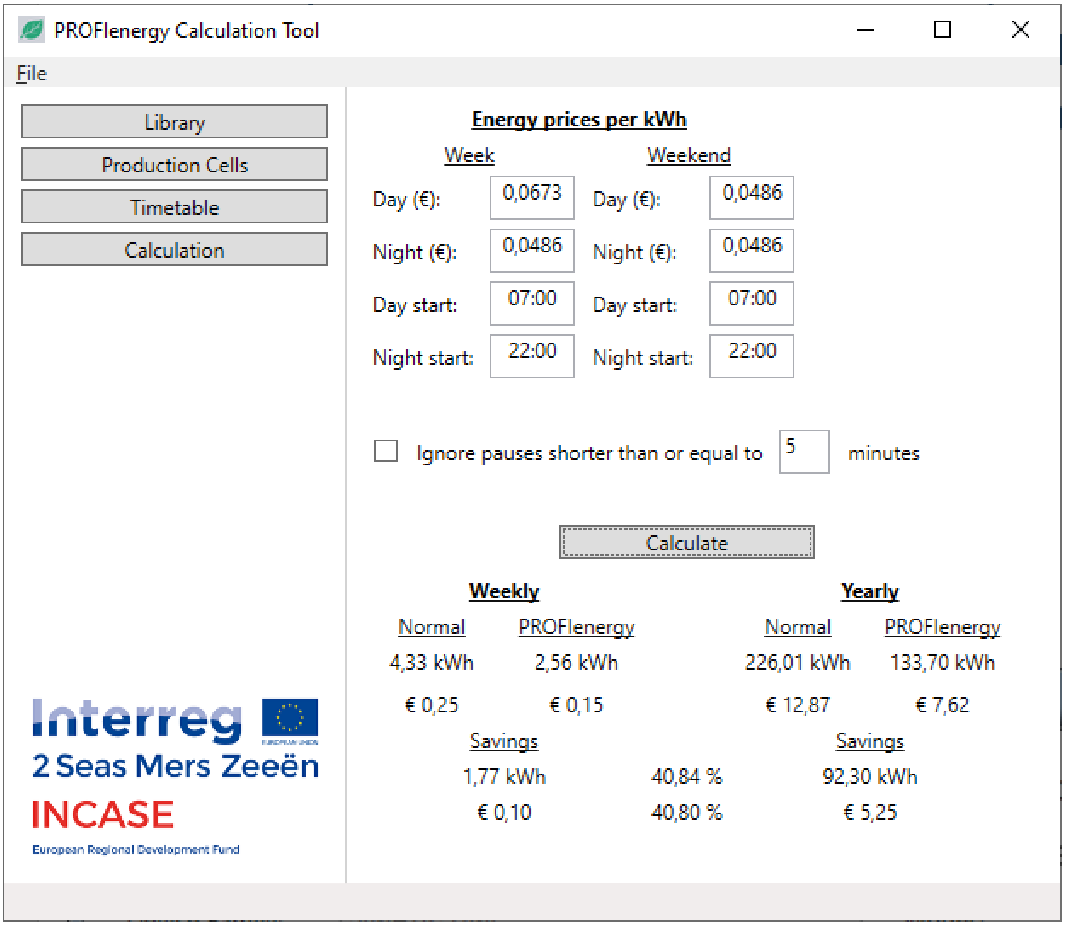


Figure 73: Calculation result for one TP1500 with the Volvo Cars standard.

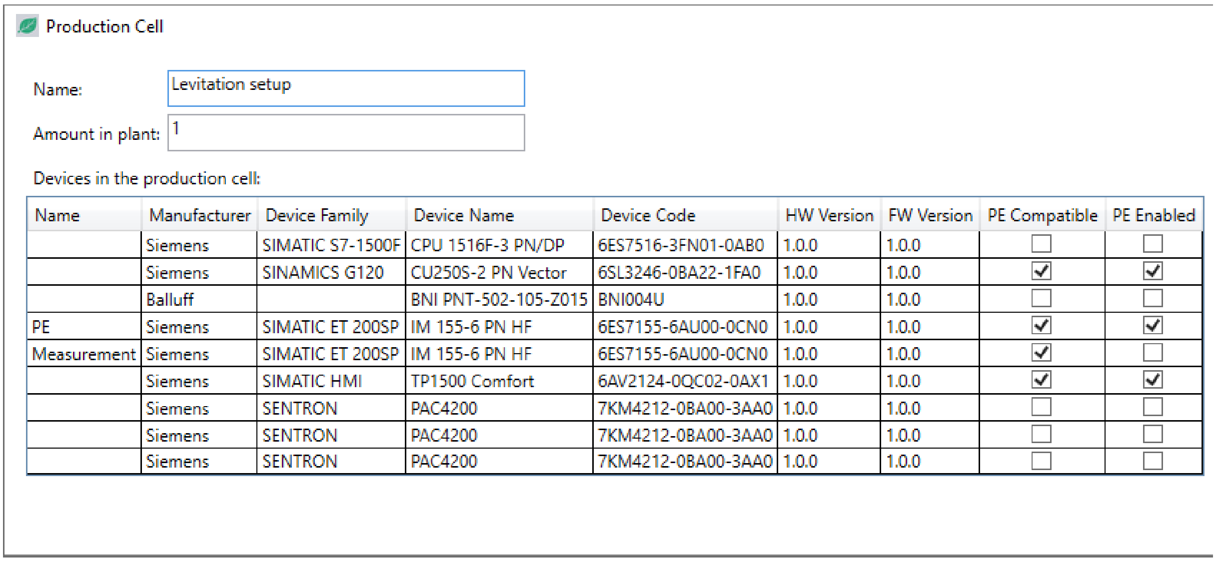
Volvo Cars Gent currently has about 150 TP1500 HMI panels, this would mean a reduction of 13.800 kWh per year. With the Belgian fuel mix in energy production, about 3.600 kg of CO_2 reduction per year (about 6.000 kg of CO_2 per year with the EU average)[7] is achieved.

[7] At medium voltage level: 262 g/kWh in BE and 432 g/kWh in EU28 [17]

7.3 Calculation tool example for the KU Leuven levitation setup (PROFIenergy, 2 shift system)

The third example is a calculation for the KU Leuven levitation setup for a 2 shift system (see 5.2 for more information).

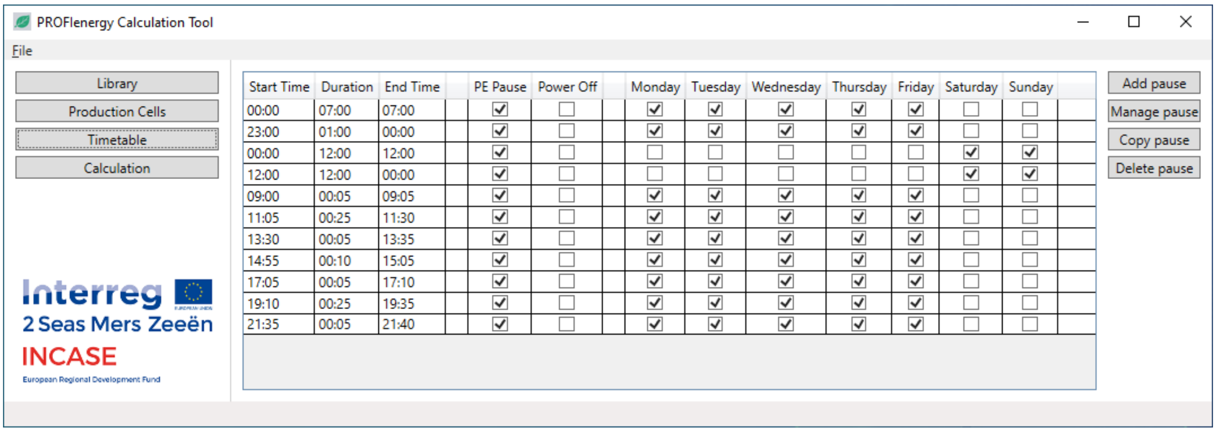
Figure 74 show the production cell used for the calculation, this production cell contains all devices used in the levitation setup. The HMI panel, the G120 drive and the ET200 SP PN IO-Device can go in PROFIenergy mode.



Name	Manufacturer	Device Family	Device Name	Device Code	HW Version	FW Version	PE Compatible	PE Enabled
	Siemens	SIMATIC S7-1500F	CPU 1516F-3 PN/DP	6ES7516-3FN01-0AB0	1.0.0	1.0.0	☐	☐
	Siemens	SINAMICS G120	CU250S-2 PN Vector	6SL3246-0BA22-1FA0	1.0.0	1.0.0	☑	☑
	Balluff		BNI PNT-502-105-Z015	BNI004U	1.0.0	1.0.0	☐	☐
PE	Siemens	SIMATIC ET 200SP	IM 155-6 PN HF	6ES7155-6AU00-0CN0	1.0.0	1.0.0	☑	☑
Measurement	Siemens	SIMATIC ET 200SP	IM 155-6 PN HF	6ES7155-6AU00-0CN0	1.0.0	1.0.0	☑	☐
	Siemens	SIMATIC HMI	TP1500 Comfort	6AV2124-0QC02-0AX1	1.0.0	1.0.0	☑	☑
	Siemens	SENTRON	PAC4200	7KM4212-0BA00-3AA0	1.0.0	1.0.0	☐	☐
	Siemens	SENTRON	PAC4200	7KM4212-0BA00-3AA0	1.0.0	1.0.0	☐	☐
	Siemens	SENTRON	PAC4200	7KM4212-0BA00-3AA0	1.0.0	1.0.0	☐	☐

Figure 74: Production cell containing all devices from the levitation setup

Figure 75 shows the timetable used for the calculation. It is a 2 shifts per day system with several pauses during the day, no work in the weekend.



Start Time	Duration	End Time	PE Pause	Power Off	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
00:00	07:00	07:00	☑	☐	☑	☑	☑	☑	☑	☐	☐
23:00	01:00	00:00	☑	☐	☑	☑	☑	☑	☑	☐	☐
00:00	12:00	12:00	☑	☐	☐	☐	☐	☐	☐	☑	☑
12:00	12:00	00:00	☑	☐	☐	☐	☐	☐	☐	☑	☑
09:00	00:05	09:05	☑	☐	☑	☑	☑	☑	☑	☐	☐
11:05	00:25	11:30	☑	☐	☑	☑	☑	☑	☑	☐	☐
13:30	00:05	13:35	☑	☐	☑	☑	☑	☑	☑	☐	☐
14:55	00:10	15:05	☑	☐	☑	☑	☑	☑	☑	☐	☐
17:05	00:05	17:10	☑	☐	☑	☑	☑	☑	☑	☐	☐
19:10	00:25	19:35	☑	☐	☑	☑	☑	☑	☑	☐	☐
21:35	00:05	21:40	☑	☐	☑	☑	☑	☑	☑	☐	☐

Figure 75: Timetable for the levitation setup (2 shift system)

Figure 76 shows the result of the calculation. This is the comparison between the unmanaged mode and the PROFIenergy mode defined for the levitation setup.

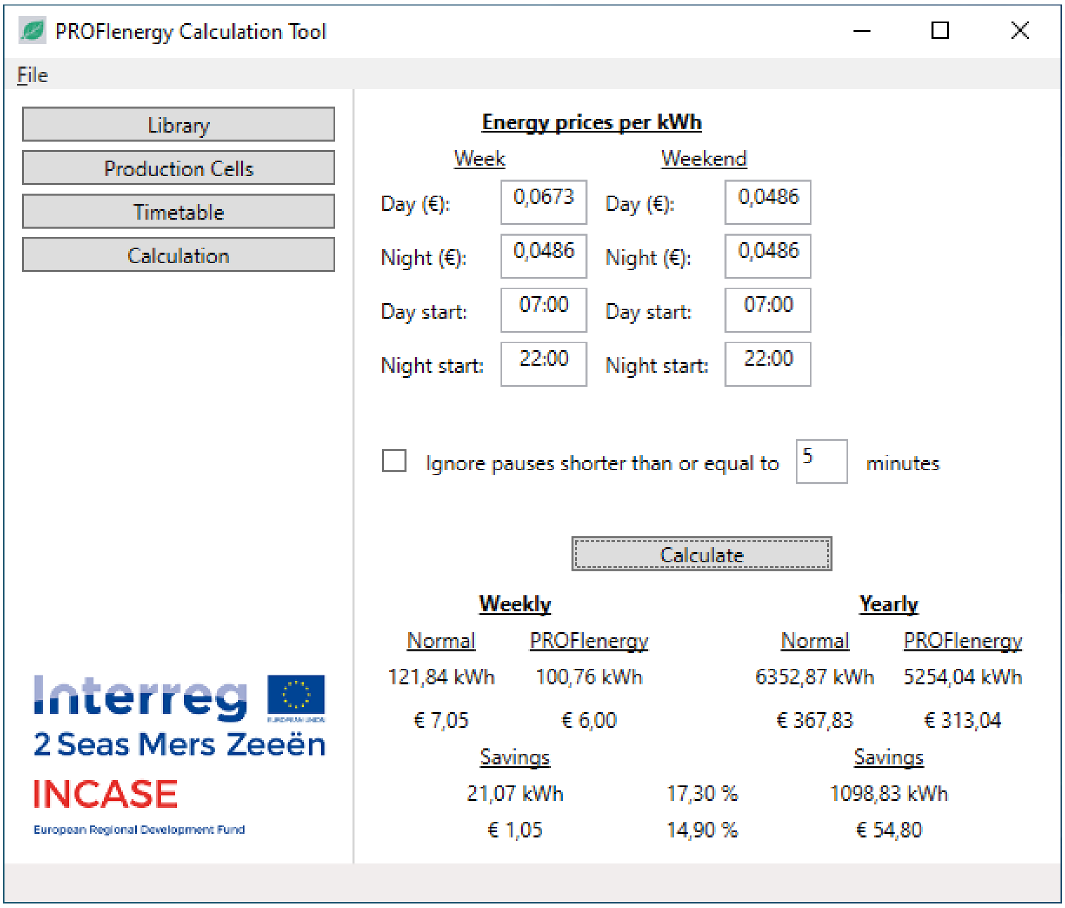
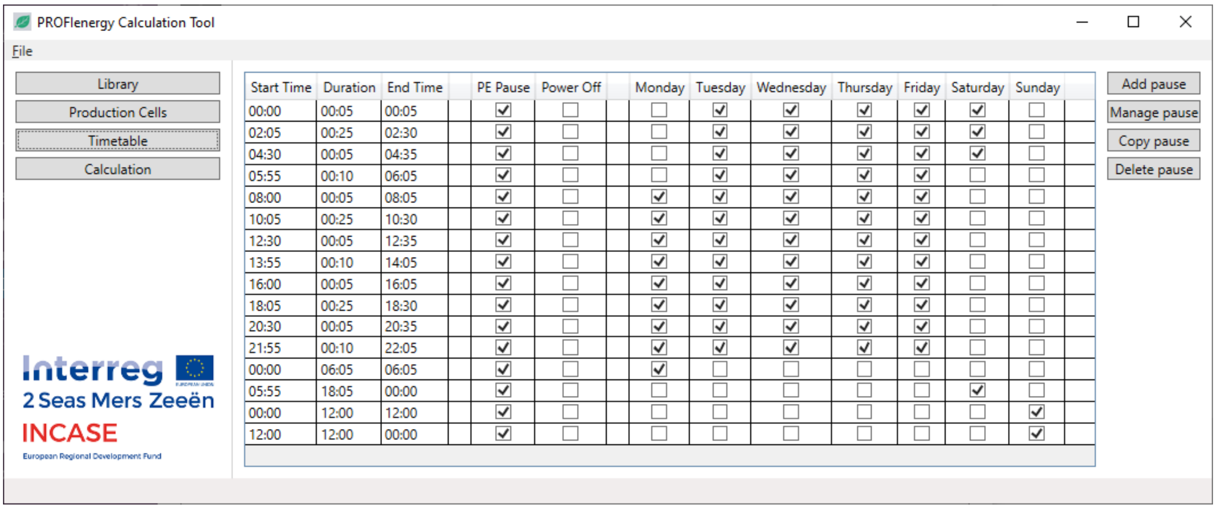


Figure 76: Result of the calculation for the levitation setup (2 shift system)

7.4 Calculation tool example for the KU Leuven levitation setup (PROFIenergy, 3 shift system)

A variation on the third example is a 3 shift system instead of a 2 shift system. The timetable can be found in Figure 77.



Start Time	Duration	End Time	PE Pause	Power Off	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
00:00	00:05	00:05	☑	☐	☐	☑	☑	☑	☑	☑	☐
02:05	00:25	02:30	☑	☐	☐	☑	☑	☑	☑	☑	☐
04:30	00:05	04:35	☑	☐	☐	☑	☑	☑	☑	☑	☐
05:55	00:10	06:05	☑	☐	☐	☑	☑	☑	☑	☐	☐
08:00	00:05	08:05	☑	☐	☑	☑	☑	☑	☑	☐	☐
10:05	00:25	10:30	☑	☐	☑	☑	☑	☑	☑	☐	☐
12:30	00:05	12:35	☑	☐	☑	☑	☑	☑	☑	☐	☐
13:55	00:10	14:05	☑	☐	☑	☑	☑	☑	☑	☐	☐
16:00	00:05	16:05	☑	☐	☑	☑	☑	☑	☑	☐	☐
18:05	00:25	18:30	☑	☐	☑	☑	☑	☑	☑	☐	☐
20:30	00:05	20:35	☑	☐	☑	☑	☑	☑	☑	☐	☐
21:55	00:10	22:05	☑	☐	☑	☑	☑	☑	☑	☐	☐
00:00	06:05	06:05	☑	☐	☑	☐	☐	☐	☐	☐	☐
05:55	18:05	00:00	☑	☐	☐	☐	☐	☐	☐	☑	☐
00:00	12:00	12:00	☑	☐	☐	☐	☐	☐	☐	☐	☑
12:00	12:00	00:00	☑	☐	☐	☐	☐	☐	☐	☐	☑

Figure 77: Timetable for the levitation setup (3 shift system)

The result of the calculation can be found in Figure 78. The savings are less significant than with a 2 shift system, because the total pause time is a lot shorter in the 3 shift system.

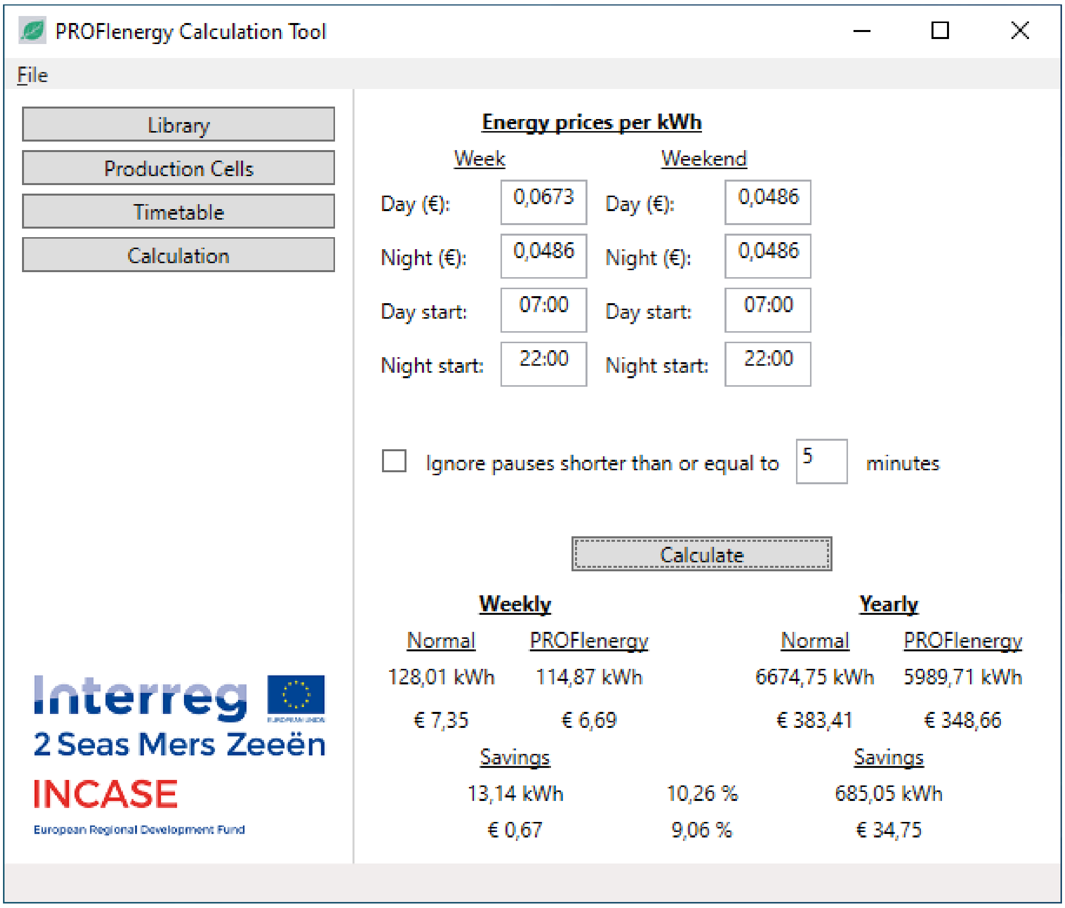


Figure 78: Result of the calculation for the levitation setup (3 shift system)

8 Conclusion and summary of the results

During the INCASE project, the PROFIenergy profile was analysed at technical level, and was demonstrated using both small and large demonstrators.

Several energy measurements were done on multiple devices. These measurements were used as input for a calculation tool that was developed during the project. The tool was used to calculate 4 use cases; the results from these 4 use cases can be found in Table 10.

Table 10: Calculated savings for 4 use cases

	1 HMI (PE, 2 shifts)	1 HMI (Volvo standard)	Levitation setup (PE, 2 shifts)	Levitation setup (PE, 3 shifts)
Energy savings	21,52%	40,84%	17,30%	10,26%
Cost savings	18,37%	40,80%	14,90%	9,06%

On component level – and in 2-shift operation – we found for typical HMI touch screens an energy saving of 21 %. Volvo Cars took – inspired by the PE idea and the energy measurements in this study – the decision to always leave touch screen HMIs (that are in their case in fact only used during error searching or checking diagnostics) in sleeping mode, to be woken up only when touched. This is strictly speaking not a PE mode, but is now being applied in the worldwide Volvo Cars automation standard: 40 % energy saving. For Volvo Cars Belgium it is a reduction of 3.600 kg of CO_2 per year (for 150 HMI panels).
On "cell" level, using the measurements on the components in a "levitation setup", calculations indicate an energy saving of about 10 resp. 17 % (3- resp. 2-shift operation).
Needless to mention that this energy saving results in lower costs and reduced CO_2 emission.

These results indicate that – for a number of applications – PROFIenergy might indeed be interesting to apply: it not only provides energy savings, but keeps the key automation components (controllers and network) active without errors, enabling fast error-free start up near the end of the (planned) pauses.

Further research and testing – after the INCASE project – will 1) allow for more components to be tested and more scenarios to be calculated for larger use cases in cooperation with Volvo Cars Gent 2) possibly lead to the development of a method to better design and implement in the automation environment 3) allow a more in deep study of the effects on diagnostic tools in the PROFINET network.

9 List of figures

10 List of tables

11 References

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