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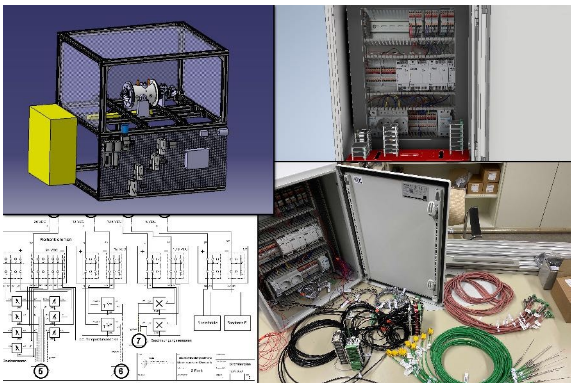
UNIVERSITY OF APPLIED SCIENCES

IFP: Measurement technology on the universal shaft test rig

Design, procurement, construction and data collection



Report

within the scope of the study program
M.Sc. Mechatronics

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1 Introduction

As part of the "Universal Shaft Test Bench" project at Darmstadt University of Applied Sciences, a test bench is to be set up to investigate an air-bearing shaft in greater detail. The shaft is a design that will be used in a microhybrid turbine [1]. The microhybrid turbine is a combination of a gas turbine and an ORC turbine, both of which are to operate on one shaft. The aim is to investigate the mechanical and thermal loads on the shaft in more detail and to derive the necessary improvements. It is also to be investigated whether an air bearing is suitable for this special application and can also be used in series production.

The task of the "Integrated Research Project" is to provide a measuring system. In order to be able to determine the loads on the test stand, appropriate sensors and measurement technology must be installed. This is the primary task of the *IFP*.

During the processing time, it was decided to use the measuring system for another project and therefore the already elaborated concept had to be extended. Thus, the task was extended to meet the new requirements:

- Measuring system concept
- Selection and procurement of the measurement system
- Modular measuring system
- Commissioning of the measuring system

The aim of this report is to document the course of the *IFP* and to show the processing steps carried out.

2 Measuring system concept

This section deals with the determination of the necessary measurement parameters.

The determination of the measured variables took place in the course of several working group meetings within the overall project. For this purpose, the requirements for the measurement technology and sensor technology were jointly determined. In a first step, hand sketches in block diagram format were developed and a system concept was graphically elaborated. In parallel, a CAD model for the design was already produced by other project participants.

2.1 Intended measurement technology

First, the physical measurands to be recorded are to be presented:

- Temperature:
  - Internal clearance
  - Cooling circuit
  - Shaft temperature
- Print
  - Internal clearance
- Speed
- Acceleration
- Gas velocity

2.2 Positioning of the sensor system

The parallel construction made it necessary to present a first concept and to determine the positioning of the sensors based on this concept:

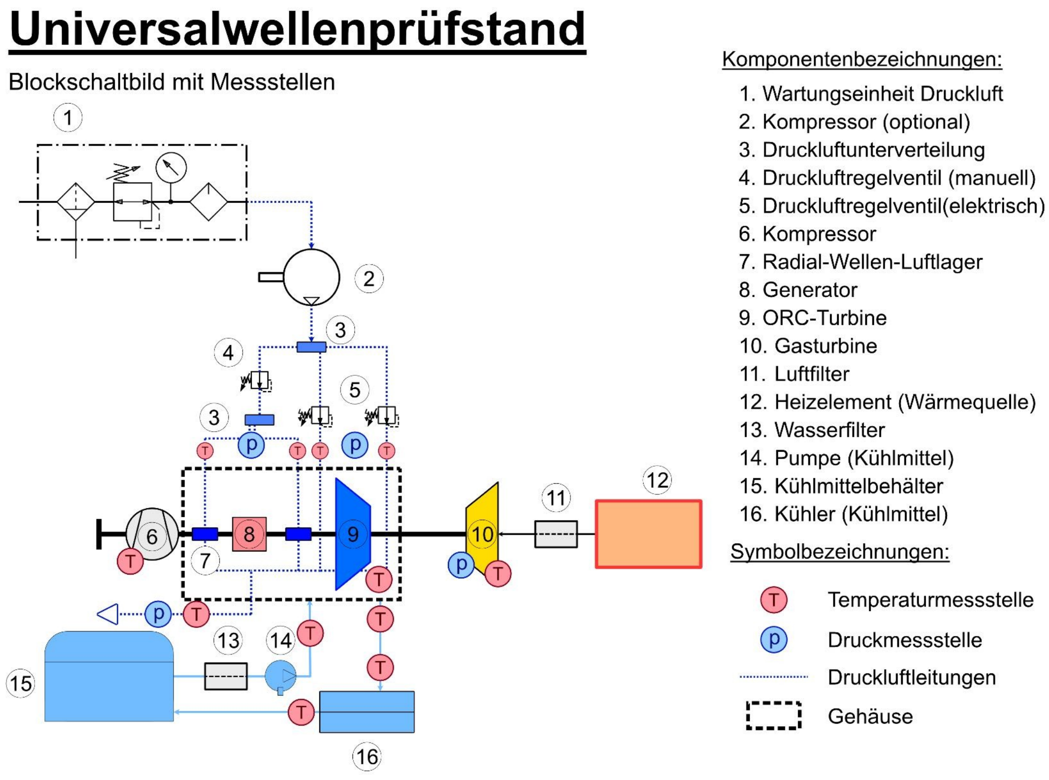


Figure 2.1: Block diagram of the universal shaft test rig

Figure 2.1 shows the structure of the individual components of the universal shaft test rig. The actuator and sensor systems of the test rig are also shown. This representation was also created in working group meetings in order to be able to determine the positioning of the sensors. After this step was completed, the positions on the real test stand could be determined in CAD. This again required close cooperation with the designer.

2.3 Iterative process

In addition, it is important to mention that the entire determination of the measurement technology was an ite- rative process. During the working group meetings several changes regarding the selection, the number and also the positioning of the sensor technology were determined. The figures presented in this report each show the most current state of development of the measurement environment. However, this approach also made it advantageous that a cost breakdown was already carried out during the planning phase and cost optimization was possible. An example of this is the adaptation of the design to the selected sensor technology to enable cost-effective implementation.

3 Selection and procurement

This chapter will now deal with the selection of the measurement technology used. The selection was documented in a project-wide parts list so that this process could be viewed by all participants at any time.

3.1 Pre-selection of components

In the first step, an online research was carried out to investigate possible sensor technology and measurement recording systems. For the measurement recording, i.e. the conversion and processing of the electrical sensor signals into a computer-controlled measurement environment, the following three feasible options emerged:

- National Instruments Hardware
- Tinkerforge Hardware
- Microcontroller

Each of these options involves a different amount of effort and expense, which will be discussed in more detail below.

Various types of sensors have also been researched for measuring temperatures on the test bench. The following useful types could be identified:

- Thermocouples
- PTC
- NTC

These sensors each offer advantages and disadvantages, which will be considered in more detail later.

Due to already existing sensor technology at the university, the following measured variables could be excluded in relation to the selection of suitable sensor technology for the pre-selection:

- Pressure sensors
- Speed sensors
- Accelerometers
- Gas velocity sensors

However, for these positions, the listed transducers also provide corresponding connection options to process the signals from the sensors.

3.2 Utility analysis

In order to be able to carry out a clear and as objective as possible comparison of the preselection, a utility value analysis was carried out. First of all, it was necessary to define criteria that are relevant for the implementation of the measurement technology on the test bench. In particular, the selection of sensors for temperature measurement and the measuring sensors had to be compared in more detail due to the wide range of offers.

Table 3.1: Utility analysis for selection of temperature sensors

Nutzwertanalyse		**Vergleich: Thermoelement, PTC, NTC**					
		Thermoelement		**PTC**		**NTC**	
Kriterium	Gewichtung	Bewertung (1-5)	Bewertung (gewichtet)	Bewertung (1-5)	Bewertung (gewichtet)	Bewertung (1-5)	Bewertung (gewichtet)
Linearität	15	3	45	5	75	1	15
Schnelligkeit	25	4	100	2	50	2	50
Genauigkeit	25	3	75	5	125	4	100
Temperaturbereich	20	5	100	3	60	1	20
Preis	15	2	30	4	60	5	75
Summe	100		350		370		260

Table 3.2: Utility analysis for sensor selection

Nutzwertanalyse		**Vergleich Messhardware: National Instruments, Tinkerforge, beliebiger Microcontroller**					
		NI-Hardware		**Tinkerforge**		**µ-Controller**	
Kriterium	Gewichtung	Bewertung (1-5)	Bewertung (gewichtet)	Bewertung (1-5)	Bewertung (gewichtet)	Bewertung (1-5)	Bewertung (gewichtet)
Messverfahren*	25	5	125	4	100	1	25
Erweiterbarkeit	25	3	75	5	125	2	50
Komfort & Handhabung*	20	4	80	5	100	1	20
Flexibilität*	10	3	30	5	50	5	50
Preis	20	1	20	4	80	5	100
Summe	100		330		455		245

* Anmerkungen:
- bewertet wurden Messgenauigkeit und Abtastrate
- einfache Installation und vielseitige Nutzungsmöglichkeiten sollten gewährleistet sein
- Wiederverwendbarkeit ist wichtig

The utility value analyses 3.1 and 3.2 visually illustrate the advantages and disadvantages of the individual options. The weightings were determined subjectively, and the evaluation of the individual points was supported by research on the Internet. The following sources were researched for this purpose:

- Transducer:
  - National Instruments [2]
  - Tinkerforge [3]
- Temperature measurements:
  - TE-connectivity [4]
  - RCT-online [5]

With the help of these analyses, the final components could now be determined. The temperature measuring points on the test bench are implemented either as PTCs or thermocouples, depending on the requirements in terms of measuring range, accuracy and measuring speed. The source of supply for the sensors has already been determined by using the hardware from *Tinkerforge,* but it was necessary to research a supplier for the selected sensor technology.

3.3 Selected components

After completing the utility analysis and price research, the following manufacturers and suppliers for the sensor and measurement technology could be determined:

- Sensors: sensorshop24.de
- Sensor: tinkerforge.com

The suppliers mentioned were convincing in terms of price-performance ratio, and the range and customization options for the necessary components are also diverse.

3.4 Procurement

In the next step, the selected measurement technology was ordered from the selected dealers. After receipt of the items at the university, they were subjected to a functional test to ensure proper operation.

4 Modular measuring system

4.1 Requirements

During processing, it became clear that a modular solution for the measurement system would be advantageous. A measuring system was also sought for another project, which deals with the construction of a test stand for the investigation of a simple steam turbine geometry. Due to the close cooperation between the project participants of both projects, it was decided to use the developed measuring system there as well. The sensor technology available there can also be used with the components procured.

Some of the selected and procured components of both projects, made it necessary to provide a voltage supply, because they already generate digitized si- gnals. An additional and constant voltage supply for the *Tinkerforge* transducers also makes sense in principle. Voltage fluctuations can possibly lead to deviations in the measured values. First, the following necessary requirements were defined:

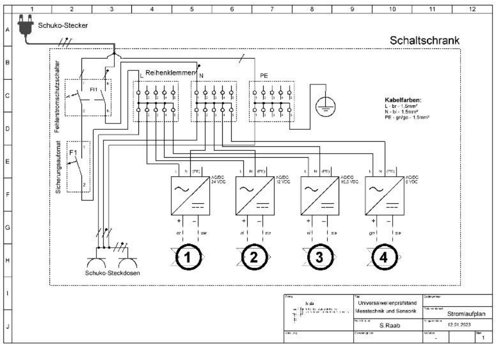
- Connection to 230 V mains possible
- Provision of DC voltages 5 V, 12 V and 24 V
- Modularity to allow use on other test stands
- Operator safety

4.2 Concept

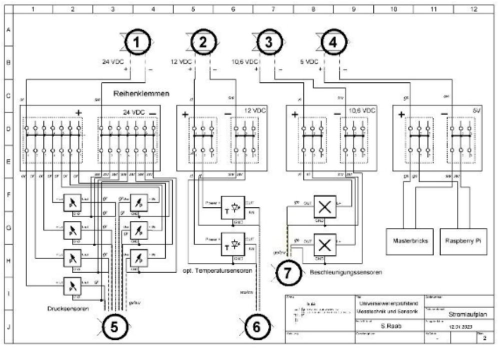
First, a concept was developed so that the given requirements could be implemented. Particular attention was paid to compliance with safety aspects. Operator safety is to be achieved by housing the components in a lockable compact control cabinet.

Since the connection to the 230V mains should be possible, an additional residual current switch is planned. The installation of the required components should be changeable at any time, which is why mounting rail profiles (TH35) should be used. Clean routing of the entire cabling is to be provided by slotted cable ducts. Changes to the cabling of the sensors and measurement technology may also be necessary during the changeover, which is why installation terminals are to be used. Likewise, two additional protective contact sockets are to be available in the control cabinet in order to be able to operate any additional components with commercially available switching power supplies.

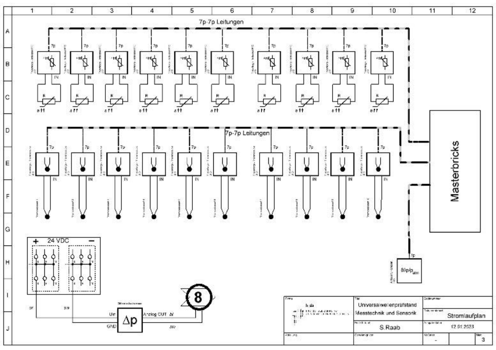
In the next step, a pre-selection of the components was made, whereby an initial cost estimate could already be made and, if necessary, lower-cost alternatives were already determined in advance. This selection was again recorded in the table already mentioned. With the help of this parts list, a current schedule was worked out to determine the order quantities and to support the construction of the measurement system. This is shown in excerpts in Figure 4.1.



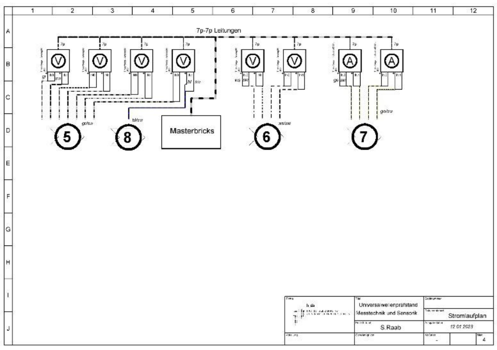
(a) Page 1



(b) Page 2



(c) Page 3

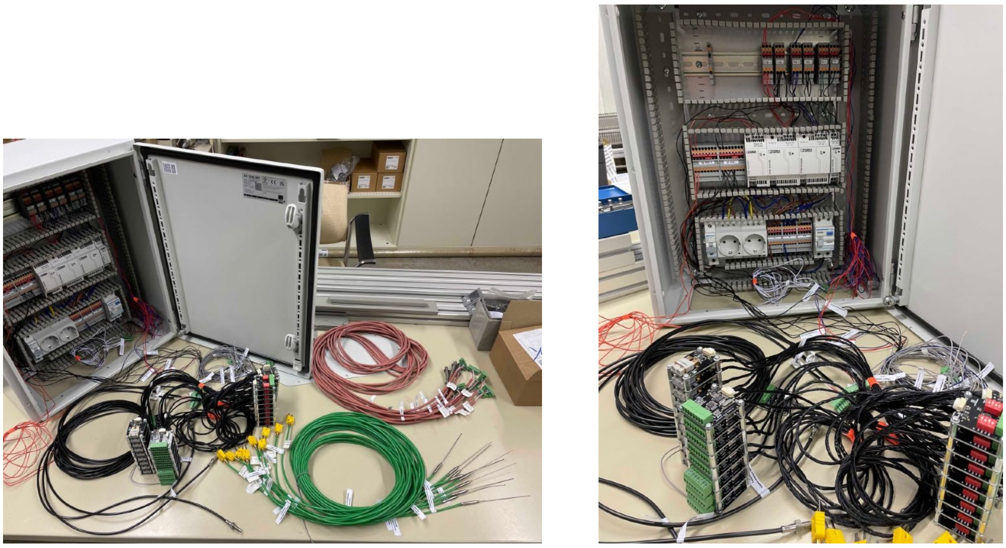


(d) Page 4

Figure 4.1: Circuit diagram of the measuring cabinet

4.3 Implementation

After completion of the concept, procurement could now take place and assembly could begin. In the first step, the compact control cabinet was assembled and equipped with the ordered components.



(a) (b)

Figure 4.2: Partially assembled measuring system

Figure 4.2 shows the current setup of the measuring system. The components and the wiring of the measuring cabinet have been made according to the circuit diagram (see: Figure: 4.1). All sensors are labeled according to their intended installation position and can thus be easily installed on the test stand. The stacked boards shown are the *Tinkerforge modules*, which are also to be placed in the measurement cabinet. For this purpose, a base plate was constructed for mounting the modules in the measuring cabinet:

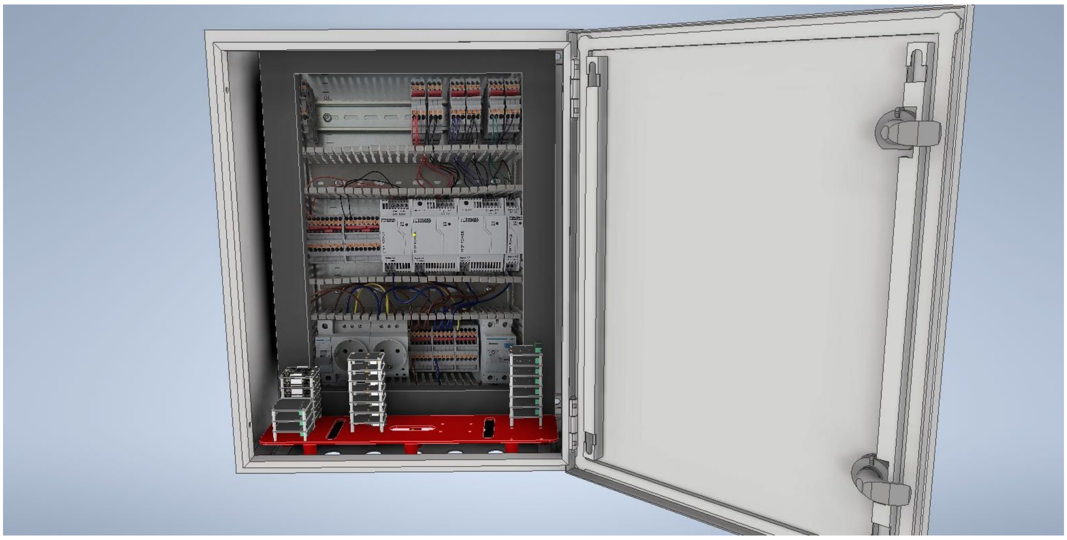


Figure 4.3: CAD model: Placement of mounting plate for Tinkerforge *mo* dule

Figure 4.3 shows the constructed mounting plate in red. This was still in production at the time of reporting and could not yet be installed in the measuring cabinet.

During the installation, the idea arose to install an additional top-hat rail profile with rail-mounted terminals directly on the test benches. In this way, the measuring cabinet and the sensors can be easily separated and the measuring technology can be used on another test stand. For this, however, it is necessary to order additional components and to document these changes accordingly (circuit diagrams, labels, etc.) These changes are then implemented in the IFWP "*Construction of a data logger as well as measurement data utilization and visualization*".

In the following chapter, however, the setup and commissioning of the measurement system will be carried out and a first test measurement will be shown.

5 Commissioning of the measuring system

5.1 Installation on the test bench

The future positioning of the sensor and measurement technology will be illustrated in this section with the aid of image sections of the CAD model of the universal shaft test rig.

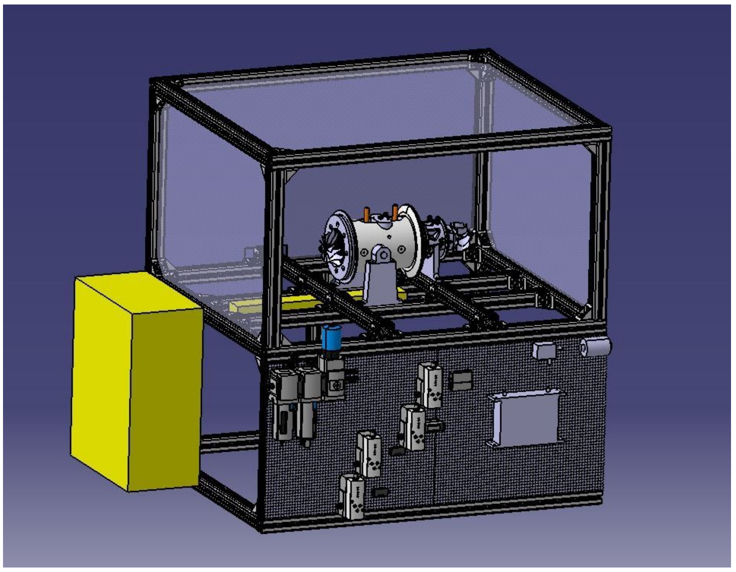


Figure 5.1: Universal shaft test bench in CATIA

Figure 5.1 shows the installation of the control cabinet and a planned cable duct with the additionally planned terminal blocks (shown in yellow). Thus, the sensor wires can be laid cleanly and are additionally protected.

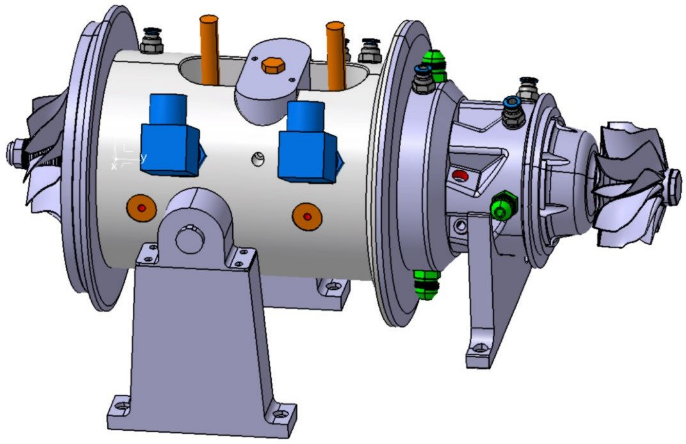


Figure 5.2: Placement of the sensors on the T turbine housing

Figure 5.2 shows the positions of the individual sensors in the turbine housing. Various temperature sensors are shown in orange. The pressure sensors (here blue) for monitoring the air pressure of the air bearings can also be seen. Further sensors are planned in measuring blocks and not installed directly on the turbine housing. These can be placed as required during assembly. Sensors in the cooling circuit have also been procured, but no design or CAD model is yet available.

5.2 Measurement software setup

The *Brickv 2.4.23* software provided by *Tinkerforge* was used to perform the measurements. With this software, the entire measurement technology was first checked for functionality. It was also necessary to update the firmware of some components to ensure proper functionality. The user interface of *Brickv 2.4.23* will now be shown.

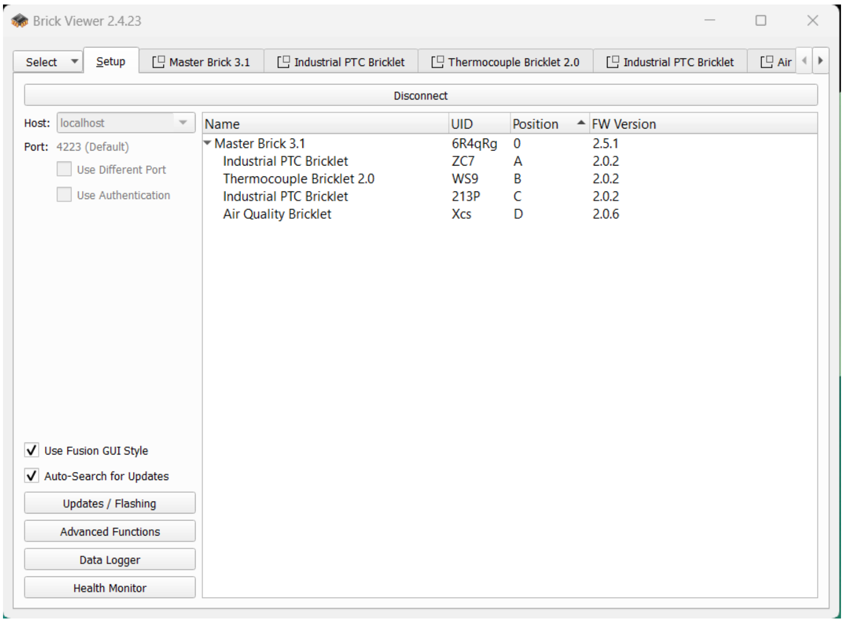


Figure 5.3: User interface of *Brickv 2.4.23*

Figure 5.3 shows the GUI of *Brickv 2.4.23 with Tinkerforge modules* connected and ve cated. With this tool sensor values can already be read out, which in case of temperature sensors already provide temperature values. For later use on the test bench, calibration may have to be performed. Here it also becomes clear that all *Tinkerforge* modules are provided with a unique "UID". These were read out accordingly and documented in tabular form.

Modulübersicht Tinkerforge

Pos. 1 ist immer das oberste Modul!

Master-Bricks

Pos.	UID	Sonstiges
1	6DbMYM	
2	6Lg19G	
3	6DAfkJ	
4	6LfgwY	
5	6koAcJ	
6	6kpADw	
7	6fd5hy	
8	6DbPcp	
9		
10		
11		

Industrial Dual Analog IN

Pos.	UID	Sensor 0	Sensor 1	Sonstiges
1	Ye9			
2	Ybj			
3	23RH			
4	YaM			
5	Ybs			
6	Ycy			
7	23RK			
8	YbX			
9				
10				
11				

Industrial Dual 0-20mA

Pos.	UID	Sensor 0	Sensor 1	Sonstiges
1	ZLW			
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

Industrial PTC

Pos.	UID	Sensor	Sonstiges
1	Ye9		
2	Ybj		
3	23RH		
4	YaM		
5	Ybs		
6	Ycy		
7	23RK		
8	YbX		
9			
10			
11			

Thermocouple

Pos.	UID	Sensor	Sonstiges
1	Ye9		
2	Ybj		
3	23RH		
4	YaM		
5	Ybs		
6	Ycy		
7	23RK		
8	YbX		
9	RHf		
10	Wta		
11			

Figure 5.4: Listing and position of the installed Tinkerforge *modules*

Figure 5.4 shows the list of the installed *Tinkerforge modules*. This list is stored as an Excel *document* on the project's cloud storage and can therefore be viewed and edited by anyone. During the setup, the installed sensors are to be assigned to the modules accordingly. This work also serves as preparation for the following IFWP, since the UIDs are needed for the programming of a visualization.

5.3 Execution and evaluation of measurements

A test measurement is now performed with the connected modules from Figure 5.3 and the corresponding sensors. For this purpose, the following sensors were connected to the appropriate Tinkerforge *modules:*

- Temperature: PTC resistor
- Temperature: Thermocouple type K
- Temperature and humidity: Ready-made module *Tinkerforge Air Quality Bricklet*

With this configuration a test measurement should be done. For this purpose the logging has to be configured in *Brickv 2.4.23:*

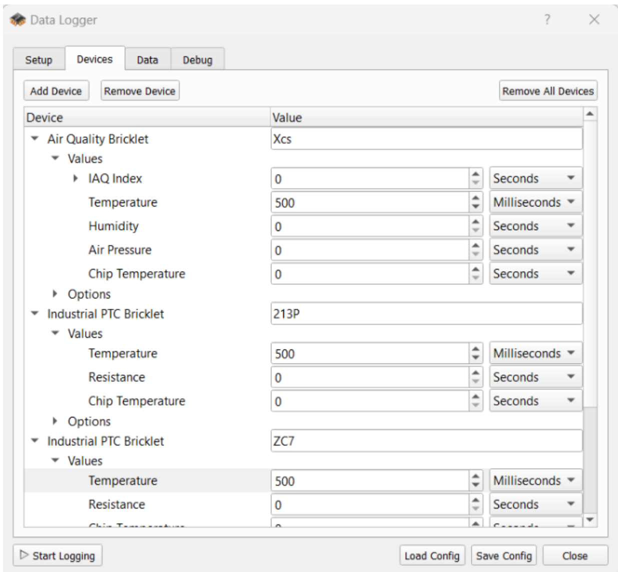


Figure 5.5: Listing and position of the installed Tinkerforge modules

Figure 5.5 shows the user interface for setting the data logging. The following time intervals for saving the measured values have been defined:

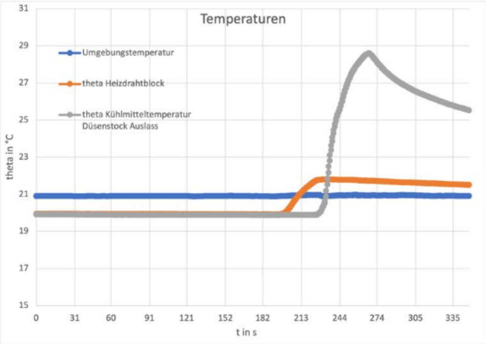
- Temperatures: 500 ms
- Humidity: 1000 ms

Also the saving of the measured values as CSV file was set before in another menu tab to enable a later evaluation. The data logging was now started and during the measurement the sensors were closed by hand to achieve a change of the measured values. The recorded measured values are now to be presented in excerpts:

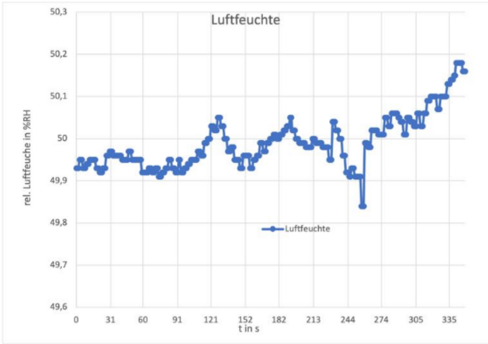
TIME	NAME	UID	VAR	RAW	UNIT
12.01.23 12:36	Air Quality Bri	Xcs	Temperature	2090	°C/100
12.01.23 12:36	Industrial PTC	ZC7	Temperature	1992	°C/100
12.01.23 12:36	Industrial PTC	213P	Temperature	1996	°C/100
12.01.23 12:36	Air Quality Bri	Xcs	Temperature	2091	°C/100
12.01.23 12:36	Industrial PTC	213P	Temperature	1996	°C/100
12.01.23 12:36	Industrial PTC	ZC7	Temperature	1992	°C/100
12.01.23 12:36	Air Quality Bri	Xcs	Humidity	4993	%RH/100
12.01.23 12:36	Air Quality Bri	Xcs	Temperature	2091	°C/100
12.01.23 12:36	Industrial PTC	ZC7	Temperature	1993	°C/100
12.01.23 12:36	Industrial PTC	213P	Temperature	1996	°C/100
12.01.23 12:36	Air Quality Bri	Xcs	Humidity	4993	%RH/100
12.01.23 12:36	Air Quality Bri	Xcs	Temperature	2091	°C/100
...	...	...	...	...	...

Figure 5.6: Extract from Datalog CS V file

Figure 5.6 clearly shows that the measurement data must be processed in order to perform a meaningful evaluation. At the later test stand it is necessary to assign the position of the sensors to the appropriate "UIDs" of the modules. For this purpose, the listing already shown (see 5.4) can be used again. Also for visualizations the data must be separated and the "RAW" values must be corrected. During the test measurement and visualization, the data was filtered by hand in *Excel* and a separate spreadsheet was created for each module. Subsequently, the measurement data were visualized in diagrams:



(a)



(b)

Figure 5.7: Visualization of the test measurement

Figure 5.7 now shows the recorded and corrected measured values of the test measurement. It should be noted that the sensors were not heated simultaneously, but one after the other. The expected changes in the temperatures can be seen. The difference in the measurement speed between a PTC resistor (orange) and a thermocouple (gray) can be seen particularly well here. The PTC resistor also takes much longer to cool down. The humidity is relatively constant over the measurement time, which was to be expected. Possibly the increase at the end can be explained by the movement in the room during the heating of the temperature measuring points. However, the deflection of the measured values is so small and generally affected by fluctuations that it can also be merely a matter of measurement inaccuracies.

6 Summary and outlook

The task of the *IFP* could be fulfilled almost completely. The measurement system for use on the universal shaft test rig was designed according to the requirements and the following results were obtained:

- Concept development
- Procurement of the components
- Structure of a modular measuring system
- Commissioning for test purposes

Particularly noteworthy is the constant development and modification of the concept, which had to be expanded and refined several times in the course of the task. Some changes were decided only shortly before the end of the *IFP,* which, however, promise es- tential improvement of the modularity and versatility of the measuring system. This process is due to the constant further development of the test rig and therefore required a high degree of flexibility in the implementation of the measurement system concept. Especially a good documentation in form of parts lists, block diagrams, construction models or this report plays an important role. Thus it would be possible to carry out a handover of the task after completion of the *IFP* and to facilitate the start of further development.

Based on the implementation of the measurement system, the following extensions and further developments would be conceivable:

- partially automated data analysis with *Microsoft Excel* or *MATLAB*
- Development of a software measurement environment with visualization of the measurement data
- Control and regulation of actuators with further Tinkerforge *modules*
- Further development into full-fledged software for monitoring and controlling the test stand

All in all, the *IFP* could be successfully processed, has enabled profound insights into the development of a measurement environment and has contributed to the fact that many new findings could be gained. It was particularly interesting to work with constantly changing requirements and the necessary adaptations. Also the various possibilities for further development of the resulting measurement system have been able to provide a deep insight into working in research.

Literature

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HOCHSCHULE DARMSTADT
UNIVERSITY OF APPLIED SCIENCES

Data logging, measurement data utilization and Visualization

Instructions for installation, setup and use on the universal shaft test stand

WiSe 2022/23

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Course of studies: M. Sc. Mechatronics

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Projects:

Universal shaft test bench and 3kW steam turbine

Content

Chapter 1 - Introduction and data flow

The main purpose of this documentation is to describe in more detail how to use the measurement system on the universal shaft test stand or 3kW test stand. This document also contains important information for the future system operator (installation instructions, accompanying documents and data integrity).

To get started, we will first briefly describe the data flow:

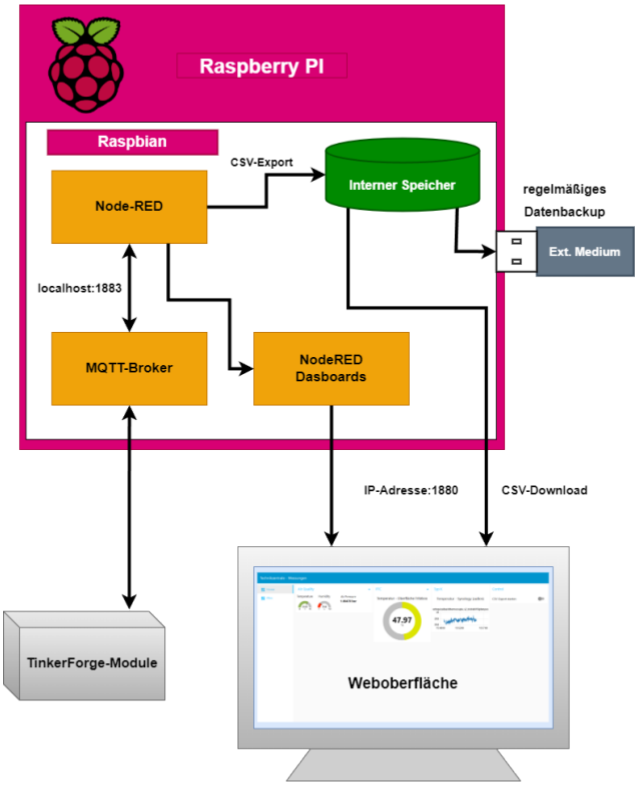

Figure 1: Data flow in the measurement system

All sensors are operated with the help of *TinkerForge* transmitters. These offer the possibility to transmit the measurement data periodically via *Message Queuing Telemetry Transport* (MQTT) after appropriate configuration. This configuration is done with the help of a *Raspberry Pi,* which simultaneously acts as an MQTT broker. It publishes the data over the standard port "1883" via TCP-IP. The evaluation and further processing of the data is done with the help of *NodeRED*. This is also installed on the *Raspberry* and provides a web application for this purpose. This can be called up via any Internet browser and is used for further processing of the measurement data. There, flow-based and using JavaScript code, the display and storage of the measured values is programmed. A web-based dashboard was also created and forms the interface for the user of the measurement environment.

After starting the measurements, the measurement data is stored as a CSV file with time stamps on the internal memory of the *Raspberry Pi* and can then be downloaded via the Dashboard. A regular backup of the measurement data to an external storage medium is also implemented.

Chapter 2 - Installation guide

This chapter is primarily intended for the system administrator. If future extensions and adjustments are necessary, the procedure described here is essential. It is also interesting for the interested user to understand the system and its installation in more detail. All steps are carried out using Windows 11 and the mentioned software for installation is partly only available for Windows. If another operating system is used, other software must be used.

Installing OS on Raspberry PI (RPi)

A Raspbian Lite installation is sufficient as a basis for the programs to be installed. This OS does without a graphical user interface, which is not necessarily needed. All installations can be performed via the command line and the upload of files is possible via FTP client. However, the installation can also be performed without problems using a *Raspbian* installation with GUI.

Instruction - Step-by-step:

1. Download Raspberry Pi Imager (02.04.2023 13:46)
2. Start, insert the appropriate Micro SD card and configure the imager:
    a. Select operating system: "*Raspberry PI OS LITE* (32-BIT)".
    b. Select SD card
    c. Gear wheel at the bottom right enables further settings:
        i. Select SSH with "Use password for authentication
        ii. Set username and password:
            - **`User: admin`**
            - **`Password: uniwelle_3kW`**
        iii. (optional) Set Wifi and language settings
    d. Press "WRITE" and wait for installation
3. Insert micro SD card into *Raspberry* and start it

Setup of the Raspberry Pi

1. Connect to *RPi* (both devices must be on the same network)
2. Launch Windows Power Shell
3. Connect to the *RPi* via SSH (see Figure 2: Connect to the RPi via SSH):
    a. Execute the following command:

```
ssh admin@192.168.xxx.xxx
```

        i. **User**
        ii. **IP address**
    b. When connecting for the first time, a prompt appears asking if this host may be trusted.
       This must be confirmed by entering "yes" and Enter
    c. After that the password of the **user** is requested
    d. If the connection is successful, you are on the command line of the *Raspberry* and can continue with the installation

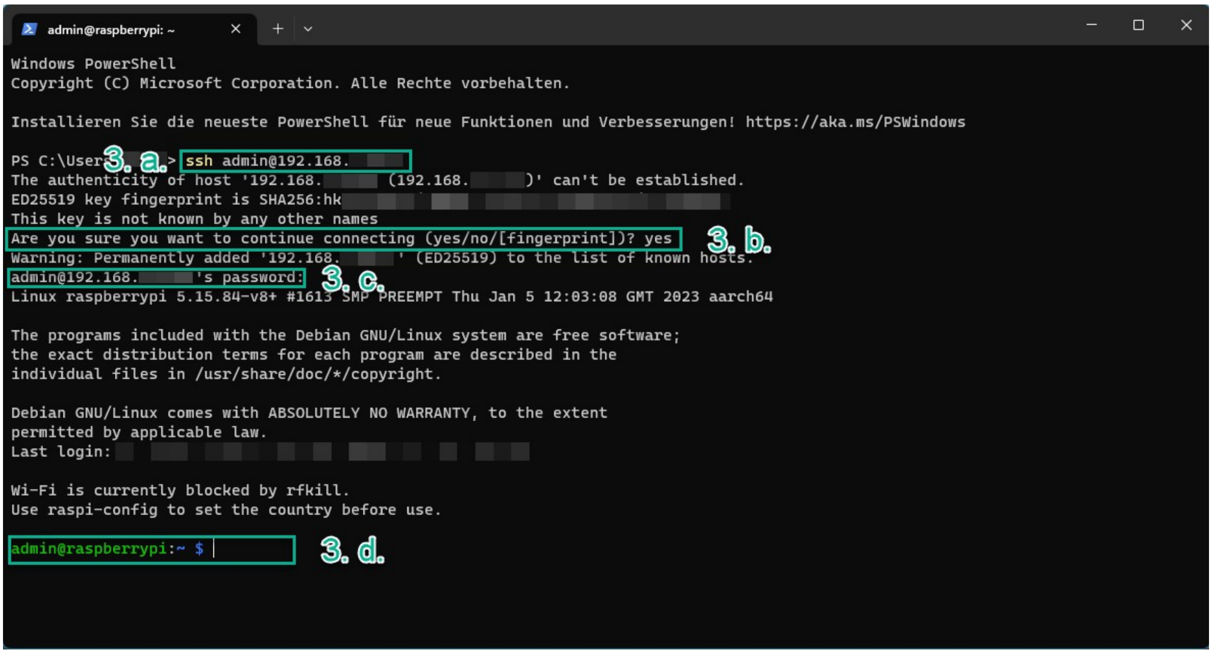

Figure 2: Connecting to the RPi via SSH

4. Perform an update of the *RPi:*

```
sudo apt update
sudo apt upgrade
```

   a. Confirm by entering "y

5. Installation of the TinkerForge *modules*:
   a. Follow the instructions:
      i. https://www.tinkerforge.com/de/doc/Software/APT_Repository.html#apt-repository (04/02/2023 13:45): Perform setup:
         1. Import GPG key
         2. Add APT repository
         3. Update APT package list
      ii. https://www.tinkerforge.com/de/doc/Software/Brickd_Install_Linux.html#brickd-install-linux (04/02/2023 13:45): *brickd* and *brickv* Install packages

```
sudo apt install brickd
sudo apt install brickv
sudo apt install tinkerforge-mqtt
```

6. Installation of *NodeRED*:
    a. Follow these instructions: https://nodered.org/docs/getting-started/raspberrypi (02.04.2023 13:55)

```
bash <(curl -sL https://raw.githubusercontent.com/node-red/linux-installers/master/deb/update-nodejs-and-nodered)
```

    b. Activate "Autostart on boot":

```
sudo systemctl enable nodered.service
```

7. Creation of a directory structure:
    a. Configuration files:

```
mkdir config
```

    b. Scripts:

```
mkdir scripts
```

    c. Measurements:

```
mkdir measurements
```

8. Setting up the Tinkerforge *modules* for MQTT transmission
    a. Installation of an FTP client for data transfer (e.g. FileZilla)
    b. Connect to the RPi (see Figure 3)
        i. Enter the network address with prefix "sftp://...", user name, password and port "22".
        ii. Press Connect and establish connection
        iii. The directory structure of the RPi is displayed on the right side (red box), the directory structure of the connected PC is on the left side (yellow box)
        iv. Files can be downloaded or uploaded via drag & drop

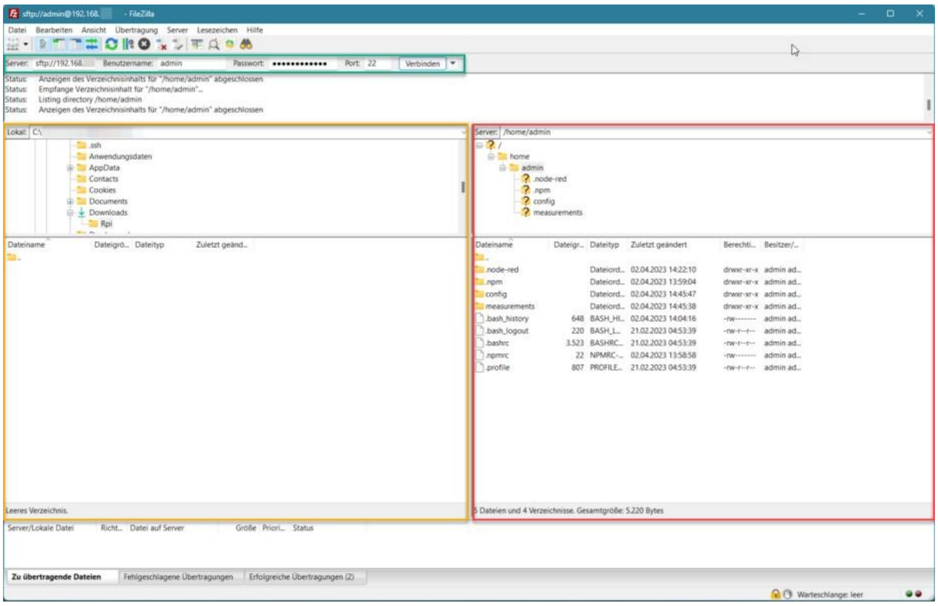

Figure 3: Connection to the Raspberry Pi via FTP for fileupload

c. Configuration file "tf_mqtt_config.txt" for the MQTT interface in "config"-. Upload folder

d. Upload script "data_backup.sh" to "scripts" folder

   i. Make script available:

```
cd scripts/
sudo cp data_backup.sh /usr/local/bin/
sudo chown root /usr/local/bin/data_backup.sh
sudo chgrp root /usr/local/bin/data_backup.sh
sudo chmod 755 /usr/local/bin/data_backup.sh
```

9. MQTT automatic configuration and data backup setup

   a. Call crontab table editing:

```
sudo crontab -e
```

   b. An editor opens where the following lines must be inserted at the end:

```
@reboot tinkerforge_mqtt --debug --broker-host localhost --broker-port 1883 --init-file /home/admin/config/tf_mqtt_config.txt
```

      i. After a reboot, the MQTT interface is automatically started with the existing configuration

```
*/5 * * * /usr/local/bin/data_backup.sh
```

      ii. Every 5 minutes the created backup script is executed and saves all measurement data to an external medium

   c. The two configuration files are described in more detail in Chapter 5 - Accompanying and video documentation and are also included as an excerpt in the appendix

Setting up the NodeRED flows

1. The interface for further setup of the NodeRED *flows* can be accessed via the IP address of the RPi's can be called:
    a. Open any Internet browser
    b. Enter the IP address with default port "1880" in the address field and confirm with Enter
    c. The user interface of *NodeRED* opens:

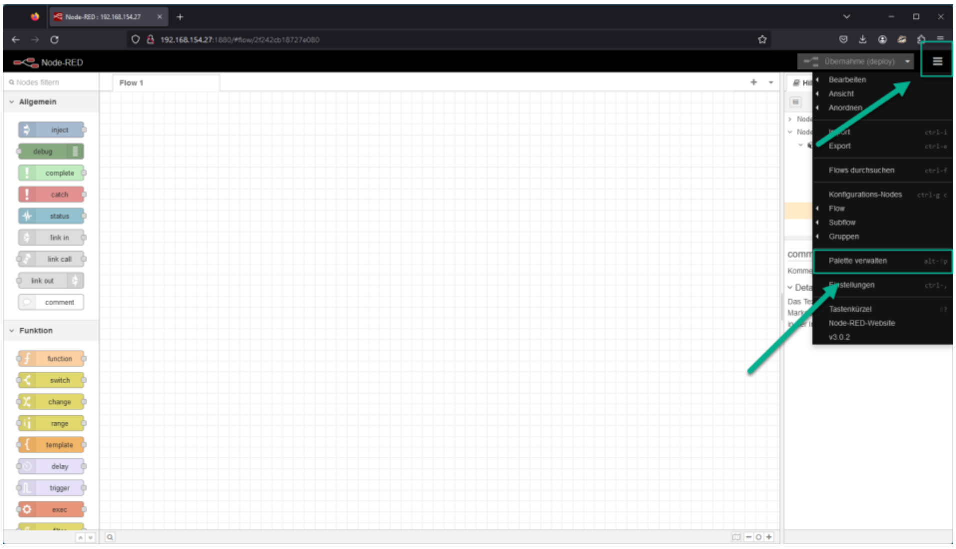

Figure 4: NodeRED user interface

    d. Under the Manage Palette setting, the following nodes must now be installed:
        i. node-red-dashboard
        ii. node-red-contrib-fs
    e. After that the provided JSON file can be imported
        i. Calling up the menu (see Figure 4)
        ii. Select import
        iii. In the import window, the appropriate ".json" file on the local computer can now be selected and imported: https://hbx.fhhrz.net/getlink/fiGJEvfLM5VM5XddNiwX5f/flows.json
        iv. After that the flows have to be deployed by clicking on "Deploy". be initialized
        v. Note: A customized file browser based on a created flow by Csongor Varga is used (https://www.youtube.com/watch?v=3QgK4IAAqcQ 02.04.2023 16:22)
2. Customization of flows/dashboards:
    a. The tab "*TinkerforgeModule*" contains the configuration of the MQTT interface to *NodeRED*, as well as a first preparation of the measurement data
    b. In the "CSV Export" tab, a timestamp is added to the measurement data and saving as a CSV file is configured
    c. In the "Dashboard" tab, the individual displays of the dashboard are configured
    d. (Optional) for test purposes, in the "TemperatureSensor" tab, the displays of the Dashboards can be described with random values
        i. Once the configuration is complete, the display nodes can be moved to the tab "Dashboard" copied and connected to the corresponding measuring points (likewise vice versa)

Chapter 3 - Application example

After completing the installation instructions, measurements on the test bench are possible. The current dashboard, which is operated with simulated measurement data, can now be accessed via a browser at the following link:

```
192.168.xxx.xxx:1880/ui/
```

Here the two trailing octets (xxx) have to be completed with the corresponding IP address. If the *Raspberry* is installed and used with graphical user interface, the following address can also be entered in the browser on the *Raspberry* with connected monitor and input devices:

```
localhost:1880/ui/
```

The browser will then display the following dashboard:

Figure 5: Dashboard of the measurement system

- In the orange area there are the configurable displays, which show the live data of the measurements or also diagrams with temporal progressions
- In the red area, the measurement can be started with the "Start CSV export" slide switch after a file name has been entered in the "Filename" input field
- In the yellow area you can switch between the dashboard display ("Home") and the download area ("Download"). In the download area, the directory in which the CSV files are stored is displayed and can be downloaded there

The dashboard is accessible from any device that is on the same network as the RPi. Smartphones and tablets are also supported by *NodeRED.*

However, should problems occur, Chapter 5 is also intended primarily as a reference. There, the accompanying and video documentation is discussed, which provides further insight into the functioning of the measurement environment and can be helpful in troubleshooting.

Chapter 4 - Data Integrity

Due to the higher error susceptibility of micro SD cards, caused by the built-in flash memory, it is necessary to secure the integrity of the data. For this purpose, two protection mechanisms were developed to protect the operating system as well as the measurement data and to enable recovery.

Backup of the measured values

For the backup of the measured values a script was developed, which periodically saves the storage directory of the measured data to an external data carrier. This can be realized by a USB stick connected to the RPi or ideally an external HDD. The mentioned backup script has already been referenced in chapter 2 (data_backup.sh) and the installation and execution has been described. The appendix of this manual contains the structure of the script, which is also part of the accompanying documentation.

Backup and restore

It must also be possible to restore the operating system and the configuration of the measurement system in the event of a failure. For this purpose, an image of the micro SD card was created, which can be loaded onto a new micro SD card with the help of the "*Raspberry Pi Imager*" tool in the event of a defect. Thus, the configuration of the measurement system is restored and the data loss is minimal. The image is also stored in a directory on the Hessenbox:

https://hbx.fhhrz.net/getlink/fiWHL1f92F9UfUwgeqF3oM/Images

In case of future changes, it is mandatory to update the image and save the new file in the directory on the Hessenbox. For this purpose, the following tool can be used and image of the micro SD card can be created (Windows operating systems only): https://win32diskimager.org/ (02.04.2023 21:03)

Chapter 5 - Accompanying and video documentation

Accompanying documentation

The following accompanying documents are part of this manual and can be adapted as necessary to document future adjustments and changes:

1. Excel table: MeasurementEquipment_TagList.xlsx
   a. Documentation of the hardware-side wiring of the TinkerForge *Bricks*
   b. Documentation of the Brick IDs on the test bench
   c. Documentation of the connected sensors (positions) on the test bench
2. Configuration file for MQTT interface of *TinkerForge* modules:
   a. Configuration of messaging via MQTT:
      i. Setting the publish period
      ii. For more options see the respective API bindings of the Bricklets (see links in the sources).
3. Data_Backup script:
   a. Specifying the location and naming of backups

The mentioned files are shown as an excerpt in the appendix but also stored in a directory on the Hessenbox:

https://hbx.fhhrz.net/getlink/fiXxtwcusPmDdnoCahNRqt/Dokumentation

Video documentation

For user

Intro:
https://hbx.fhhrz.net/getlink/fiSmWJdsbJkpyPL9fifP1P/00_Messsystem_Intro.mp4

Using the Dashboard:
https://hbx.fhhrz.net/getlink/fiEhiNwHgf4dQt4gCfaCSv/06_Messsystem_Dashboard-Introduction.mp4

For system administrators and interested parties

Configuration of the TinkerForge modules:
https://hbx.fhhrz.net/getlink/fiWSbR1NCQmtSAh9hFtpBB/01_Messsystem_TF-Module.mp4

Set up measurements as CSV file:
https://hbx.fhhrz.net/getlink/fiFA5PDzyRMBb2r1Y1XLJv/02_Messsystem_CSV.mp4

Configuration of the dashboard flow:
https://hbx.fhhrz.net/getlink/fiMyb7o3DHfV6XheK71Yki/03_Messsystem_Konfig-Dashboard.mp4

Configuration of the file browser in the dashboard:
https://hbx.fhhrz.net/getlink/fi6pbidvsB3DJbwZvd4EEb/04_Messsystem_Filebrowser.mp4

Measuring point simulation:
https://hbx.fhhrz.net/getlink/fi4TxHFL69qTji142uYdnc/05_Messsystem_SensorSim.mp4

Chapter 6 - Outlook

The measuring system presented here is not intended to be a final version, but above all to invite future users to further improve and expand the system. During the development and construction some ideas came up, which extensions or improvements could be implemented. These will now be listed briefly:

- Dashboard enhancement:
  - Implementation of further/customized visualizations
- Extension of the system:
  - Install and integrate additional measuring points
  - Extension to test bench control system by installation/implementation of actuators/displays/controllers
- Storage of measurement data on an outsourced database (local/web)
  - Interesting solution: InfluxDB v2.x with integrated web server for data download and initial visualization
    - Idea for a tag list is listed Excel file of the accompanying documentation
    - 64-bit operating system on *Raspberry* mandatory

Sources:

In this section all sources are listed, which were useful during the development of the system. These do not necessarily have to be mentioned in the manual, but may provide good reference points for future development:

Installing the operating system - Raspbian OS:

- https://www.raspberrypi.com/software/ (02.04.2023 11:57)

Useful links for using the command line via SSH:

- https://wiki.ubuntuusers.de/Shell/Bash-Skripting-Guide_f%C3%BCr_Anf%C3%A4nger/ 12.03.2023 11:47
- https://wiki.ubuntuusers.de/mkdir/ 12.03.2023 13:59
- https://wiki.ubuntuusers.de/cp/ 12.03.2023 14:18
- https://wiki.ubuntuusers.de/Cron/ 12.03.2023 14:27

Setup of the TinkerForge MQTT interface:

- https://www.tinkerforge.com/de/doc/Software/APT_Repository.html#apt-repository (02.04.2023 13:45)
- https://www.tinkerforge.com/de/doc/Software/Brickd_Install_Linux.html#brickd-install-linux (02.04.2023 13:45)

All on 17.03.2023 21:24:

- https://www.tinkerforge.com/de/doc/Software/Bricklets_MQTT.html
- https://www.tinkerforge.com/de/doc/Software/Bricklets/IndustrialDualAnalogInV2_Bricklet_MQTT.html#industrial-dual-analog-in-v2-bricklet-mqtt-api
- https://www.tinkerforge.com/de/doc/Software/Bricklets/ThermocoupleV2_Bricklet_MQTT.html#thermocouple-v2-bricklet-mqtt-api
- https://www.tinkerforge.com/de/doc/Software/Bricklets/IndustrialPTC_Bricklet_MQTT.html#industrial-ptc-bricklet-mqtt-api
- https://www.tinkerforge.com/de/doc/Software/Bricklets/IndustrialDual020mAV2_Bricklet_MQTT.html#register/industrial_dual_0_20ma_v2_bricklet/%3CUID%3E/current
- https://www.tinkerforge.com/de/doc/Software/Bricklets/IndustrialDual020mAV2_Bricklet_MQTT.html#industrial-dual-0-20ma-v2-bricklet-mqtt-examples

Setup of the NodeRED environment:

- https://nodered.org/docs/getting-started/raspberrypi (02.04.2023 13:55)
- https://www.youtube.com/watch?v=3QgK4IAAqcQ (02.04.2023 16:22)

Advanced tools for testing, configuring and simulating the MQTT interface:

- https://mosquitto.org/man/mosquitto_pub-1.html (03/17/2013 16:29)
- http://www.steves-internet-guide.com/mosquitto_pub-sub-clients/ (03/17/2013 16:29)

Appendix

Configuration file of the MQTT interface:


```
{

    "tinkerforge/request/industrial_ptc_bricklet/ZC7/set_temperature_callback_configuration":{"period": 2000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_ptc_bricklet/ZC7/temperature":{"register": true},

    "tinkerforge/request/industrial_ptc_bricklet/213P/set_temperature_callback_configuration":{"period": 2000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_ptc_bricklet/213P/temperature":{"register": true},

    "tinkerforge/request/industrial_ptc_bricklet/ZCb/set_temperature_callback_configuration":{"period": 2000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_ptc_bricklet/ZCb/temperature":{"register": true},

    "tinkerforge/request/industrial_ptc_bricklet/213q/set_temperature_callback_configuration":{"period": 2000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_ptc_bricklet/213q/temperature":{"register": true},

    "tinkerforge/request/industrial_ptc_bricklet/213h/set_temperature_callback_configuration":{"period": 2000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_ptc_bricklet/213h/temperature":{"register": true},

    "tinkerforge/request/industrial_ptc_bricklet/ZC6/set_temperature_callback_configuration":{"period": 2000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_ptc_bricklet/ZC6/temperature":{"register": true},

    "tinkerforge/request/industrial_ptc_bricklet/ZC8/set_temperature_callback_configuration":{"period": 2000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_ptc_bricklet/ZC8/temperature":{"register": true},

    "tinkerforge/request/industrial_ptc_bricklet/213s/set_temperature_callback_configuration":{"period": 2000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_ptc_bricklet/213s/temperature":{"register": true},


    "tinkerforge/request/thermocouple_v2_bricklet/WS9/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/WS9/temperature":{"register": true},

    "tinkerforge/request/thermocouple_v2_bricklet/WpR/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/WpR/temperature":{"register": true},

    "tinkerforge/request/thermocouple_v2_bricklet/Wso/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/Wso/temperature":{"register": true},

    "tinkerforge/request/thermocouple_v2_bricklet/WQg/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/WQg/temperature":{"register": true},

    "tinkerforge/request/thermocouple_v2_bricklet/WSc/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/WSc/temperature":{"register": true},

    "tinkerforge/request/thermocouple_v2_bricklet/WPY/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/WPY/temperature":{"register": true},

    "tinkerforge/request/thermocouple_v2_bricklet/WRf/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/WRf/temperature":{"register": true},

    "tinkerforge/request/thermocouple_v2_bricklet/WQq/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/WQq/temperature":{"register": true},

    "tinkerforge/request/thermocouple_v2_bricklet/WPJ/set_temperature_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/thermocouple_v2_bricklet/WPJ/temperature":{"register": true},


    "tinkerforge/request/industrial_dual_0_20ma_v2_bricklet/ZLW/set_current_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 3000, "max": 0},
    "tinkerforge/register/industrial_dual_0_20ma_v2_bricklet/ZLW/current":{"register": true},


    "tinkerforge/request/industrial_dual_analog_in_v2_bricklet/Ye9/get_all_voltages_callback_configuration":{"period": 1000, "value_has_to_change": false},
    "tinkerforge/register/industrial_dual_analog_in_v2_bricklet/Ye9/voltage":{"register": true},

    "tinkerforge/request/industrial_dual_analog_in_v2_bricklet/Ybj/get_all_voltages_callback_configuration":{"period": 1000, "value_has_to_change": false},
    "tinkerforge/register/industrial_dual_analog_in_v2_bricklet/Ybj/voltage":{"register": true},

    "tinkerforge/request/industrial_dual_analog_in_v2_bricklet/23RH/get_all_voltages_callback_configuration":{"period": 1000, "value_has_to_change": false},
    "tinkerforge/register/industrial_dual_analog_in_v2_bricklet/23RH/voltage":{"register": true},

    "tinkerforge/request/industrial_dual_analog_in_v2_bricklet/YaM/get_all_voltages_callback_configuration":{"period": 1000, "value_has_to_change": false},
    "tinkerforge/register/industrial_dual_analog_in_v2_bricklet/YaM/voltage":{"register": true},

    "tinkerforge/request/industrial_dual_analog_in_v2_bricklet/Ybs/get_all_voltages_callback_configuration":{"period": 1000, "value_has_to_change": false},
    "tinkerforge/register/industrial_dual_analog_in_v2_bricklet/Ybs/voltage":{"register": true},

    "tinkerforge/request/industrial_dual_analog_in_v2_bricklet/Ycy/get_all_voltages_callback_configuration":{"period": 1000, "value_has_to_change": false},
    "tinkerforge/register/industrial_dual_analog_in_v2_bricklet/Ycy/voltage":{"register": true},

    "tinkerforge/request/industrial_dual_analog_in_v2_bricklet/23RK/get_all_voltages_callback_configuration":{"period": 1000, "value_has_to_change": false},
    "tinkerforge/register/industrial_dual_analog_in_v2_bricklet/23RK/voltage":{"register": true},

    "tinkerforge/request/industrial_dual_analog_in_v2_bricklet/YbX/get_all_voltages_callback_configuration":{"period": 1000, "value_has_to_change": false},
    "tinkerforge/register/industrial_dual_analog_in_v2_bricklet/YbX/voltage":{"register": true},


    "tinkerforge/request/air_quality_bricklet/X9A/set_all_values_callback_configuration":{"period": 1000, "value_has_to_change": false, "option": "x", "min": 0, "max": 0},
    "tinkerforge/register/air_quality_bricklet/X9A/all_values":{"register": true}

}
```


A text file is located in the following directory on the Hessenbox:

https://hbx.fhhrz.net/getlink/fi9XBFtNSsbQVjUEaRQ8dP/Konfigurationsdateien

Backup script

```bash
#!/bin/bash

datum=$(date +'%Y-%m-%d')
quelle=/home/admin/measurements
ziel1=/home/admin/backups/$datum
ziel2=/media/usb/backups/$datum

sudo mkdir $ziel1 $ziel2
sudo cp -uvr $quelle $ziel1
sudo cp -uvr $quelle $ziel2

```

The script is located in the following directory on the Hessenbox:

https://hbx.fhhrz.net/getlink/fi9XBFtNSsbQVjUEaRQ8dP/Konfigurationsdateien