Bachelor thesis

Design of the motion control for a test rig analyzing rotation and expansion performing assemblies in parabolic trough collector power plant applications

Tobias Hilbel

Study course: Power Engineering and Renewable Energies

Department of Electrical Engineering
Hochschule Mannheim University of Applied Sciences

December 2016

For:
German Aerospace Center (DLR)
Institute of Solar Research

Supervision and Assessment:
Prof. Dr. M. Junker, HS Mannheim
Dipl.-Ing. C. Hilgert, DLR

hochschule mannheim

DLR

Statement of Authorship

This dissertation is the result of my own work. Material from the published or unpublished work of others, which is referred to in the dissertation, is credited to the author in the text.

Place, date

Signature

Abstract

Parabolic Trough Collector (PTC) power plants collect the sun's energy as heat. The heat can be stored and used to produce electrical energy or process heat. PTCs are the widest spread Concentrated Solar Power (CSP) technology. Elementary components in PTC power plants are Rotation and Expansion Performing Assemblies (REPAs). These REPAs serve to establish a connection between the expanding and rotating Heat Collection Element (HCE) and the rigid tubing system. Since REPAs are elements that are subjected to high stress levels a test rig is built, allowing investigation on durability and REPA failure. The task to perform realistic durability tests in an accelerated manner, leads to special requirements on the motions executed by the test rig. The present bachelor thesis describes the development of the motion control system for the REPA test rig. To provide a better understanding of the context a brief overview of CSP, PTC and REPA technologies is given. Subsequently, knowing the requirements, the design of the test rig is presented. In the main part of the thesis the arrangement of the motion control, its integration in the Supervisory Control and Data Acquisition (SCADA) system, as well as the chosen hardware is discussed. Further on, the programmed functions and the specifications of the motion control system are described. The development process led to a system enabling the test rig to reproduce a translational motion in a 45° range and a rotational motion between -120° and +90°. Whereby these motions are produced using cylinders, which are controlled by a hydraulic unit. To control the speed of the motion and enable the execution of 0.25° steps in the rotation axis a Variable Speed Drive (VFD) and a servo motor with servo controller are driving two separated hydraulic pumps. The motion functions, implemented on a SIMATIC S7-300 Programmable Logic Controller (PLC), enable the above described motions as well as a positioning at position set points. The correct function of the developed system is not yet verified. A discussion of the influence of the PLC cycle time and a comparison with an existing PTC system is carried out. Ultimately a summary of the motion control parameters and specifications are given.

Terminology and abbreviations

The following terminology and units are used throughout this report:
Abbreviations

µP	Microprocessor
ABS	Absolute
ADC	Analog-to-Digital Converter
AI	Analog Input
AO	Analog Output
BJA	Ball Joint Assemblies
CA	Critical Angle
CAD	Computer-Aided Design
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
CPU	Central Processing Unit
CSP	Concentrated Solar Power
DAC	Digital-to-Analog Converter
DB	Data Block
DI	Digital Input
DIFF	Differential
DNI	Direct Normal Irradiation
DLR	German Aerospace Center / Deutsche Zentrum für Luft- und Raumfahrt e. V.
DO	Digital Output
ERR	Error
ESD	Emergency Shut Down
FC	Function
FFPROM	Electrically Erasable Programmable Read-Only Memory
GUI	Graphical User Interface
HCE	Heat Collecting Element
HL	High Limit
HMI	Human machine interface
HTF	Heat Transfer Fluid
LAN	Local-Area Network
LD	Ladder Diagram
LL	Low Limit
LSB	Least Significant Bit
LV	LabView
OPC	Open Platform Communications
OS	Operating System
PC	Personal Computer
PLC	Programmable Logic Controller
POS	Position
PRE	Pressure
PTC	Parabolic Trough Collector
RAM	Random Access Memory
REPA	Rotation and Expansion Performing Assembly
RFHA	Rotary Flex Hose Assemblies
ROT/rot	Rotation
RTD	Resistance Temperature Detector
RTOS	Real-time operating system
SP	Set Point

STL	Statement List
SW	Switch
T	Temperature
TRA/tra	Translation
UPS	Uninterruptible Power Supply
VFD	Variable-frequency Drive

Symbols:

φ	Rotation angle phi
θ	Translation angle theta
R	Resolution
Δ	Change / difference
$\Delta\varphi$	Maximum change of the rotation angle φ within one program cycle
ω	Angular velocity
u	Tolerance
T	Cycle time

Table of contents

1 Introduction

Due to increasing energy demands and climate change, alternatives to conventional fossil energy sources are needed.
Carbon dioxide emissions can be reduce by further enlargement of renewables and replacement of fossil energy sources, which is necessary to slow down the climate change. [IPCC] [1]
The usage of solar energy has an especially high potential in areas of high sun irradiation and can significantly contribute to electrical power supply [2].
A major advantage of solar thermal power plants, compared to most other options of renewable power generation, is the possibility to store thermal energy and therefore to supply dispatch capacities.
Most of such thermal power plants use concentrated solar power (CSP) technology. Due to the concentration process these technologies have their best potential in areas with a high direct solar irradiation [2]. Figure 1 shows the average worldwide DNI.

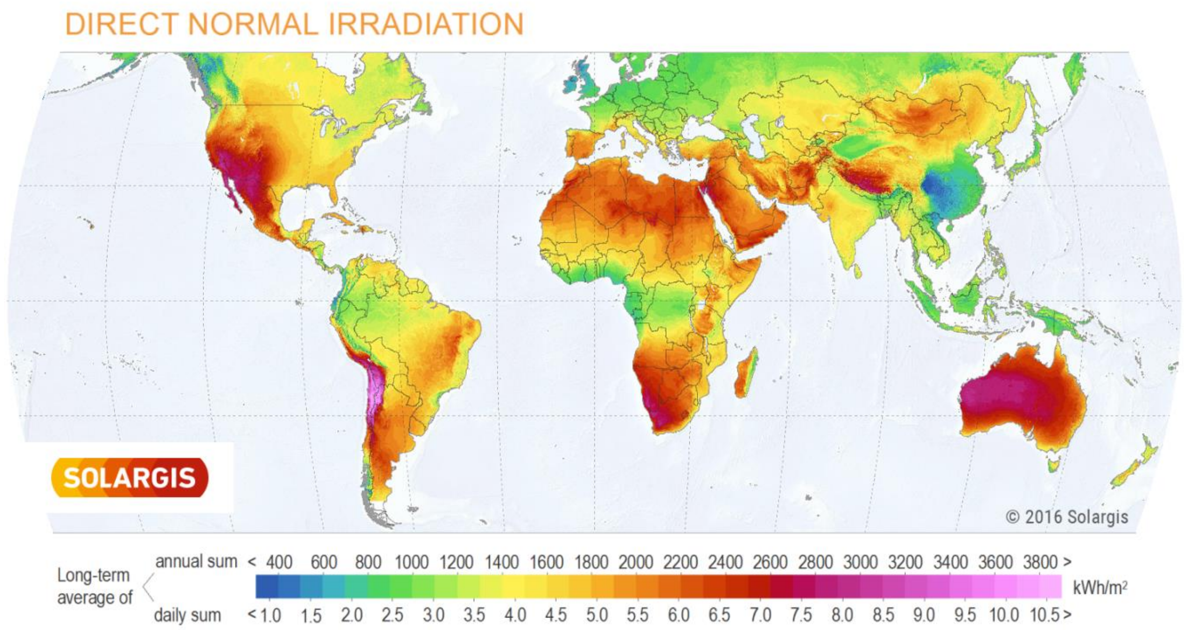


Figure 1: Average worldwide annual and daily DNI on a horizontal plane [3]

1.1 Concentrated solar power

Concentrated Solar Power (CSP) plants collect the sun's energy as heat, store that heat if needed, and finally transport it to a power block in which the heat is transformed to electricity by a steam or a gas turbine.
To increase temperature and efficiency, CSP technology uses large mirrors to concentrate sunlight onto a small receiver (solar towers or solar parabolic dishes) or onto long receiver pipes (linear Fresnel collectors or parabolic troughs).

1.2 Parabolic trough

The parabolic trough collectors (PTCs) are the widest spread commercial CSP technology at the moment. The fundamental elements of parabolic trough collectors are parabolic shaped mirrors and an absorber tube, also called Heat Collecting Element (HCE), where the HCE is located in the focal point of the reflectors.
For most commercial applications, the longitudinal axis of the structure follows a north south orientation. In order to follow the sun´s movement, a one axis tracking system, moving in east-west direction is used. This constellation leads usually to a higher annual average. Nevertheless, for investigation purpose or for locations of higher latitude, an east west alignment of the structure in combination with a south –north or even a two axis tacking system might be more suitable. The schematic drawing in Figure 2 demonstrates the principle of a parabolic trough collector system.

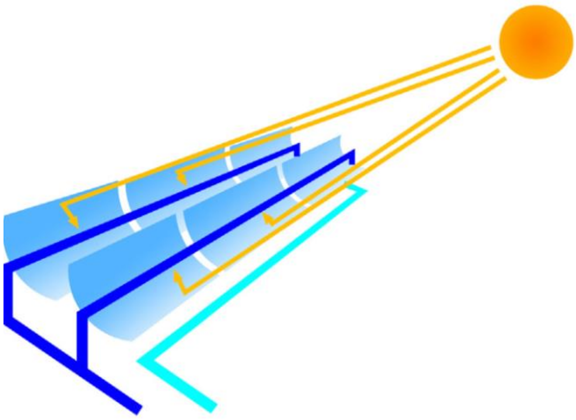


Figure 2: Scheme of parabolic trough [4]

A Heat Transfer Fluid (HTF) is pumped through the absorber tube. Typically HTFs are thermal oils which can be can be heated to temperatures of up to 400 °C (state of art, upcoming silicon oils allow temperatures of up to 450 °C). At a heat exchanger, the heat is transferred to either a Thermal Energy Storage (TES), water or steam. The steam drives a generator to produce electricity or can be used as process energy. Figure 3 shows a photo of four *“Euro Trough”* solar collector elements at the PSA [5].

Figure 3: “*EuroTrough*“ solar collector elements [5]

1.2.1 Tracking methods

Good sun tracking is essential to obtain high efficiency and can be achieved by the use of different methods and technologies. Generalizing, it can be said that there are two main methods: astronomical and optical tracking systems. The astronomical tracking is an open loop system based on exact location- and alignment data of the PTC. By astronomical data the position of the sun at each time is known. With the help of algorithms the needed collector orientation, to obtain an optimum focus at the HCE, can be determined. Finally the PTC is moved to the position via a motion control system consisting of a hydraulic drive and a position sensor. In contrast, optical tracking systems use sun sensors to measure the difference between the actual position and the optimal position to center the HCE within the focus. Such a sun sensor is shown in Figure 4. The optimum orientation is achieved by a closed loop control. Even though using a sun sensor, it would not be necessary to know the current position of the collector to achieve an optimum orientation the position value is still needed to guarantee the function of the hydraulic drive. Hence, inclinometers (as shown in appendix 14.13) are commonly used for commercial PTC applications. Furthermore there are tracking systems that use a combination of both, astronomical and optical tracking systems. [6]

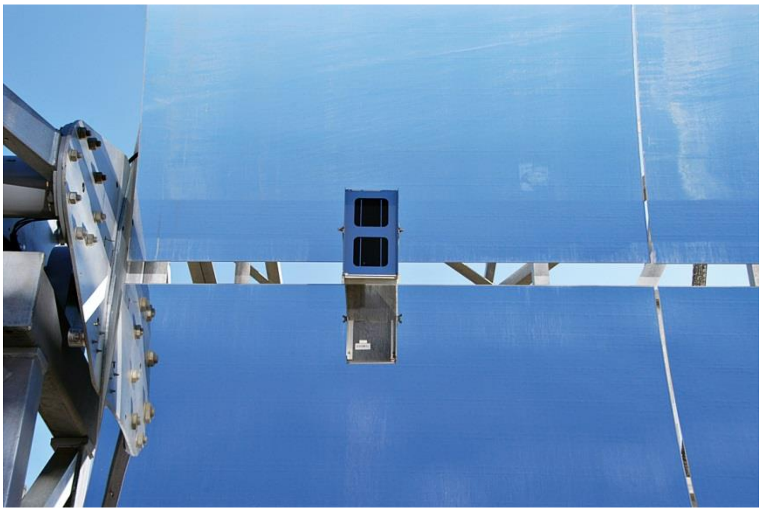


Figure 4: Sun sensor on PTC [7]

1.2.2 Solar field design

The series connection of multiple Solar Collector Elements (SCE) forms a Solar Collector Assembly (SCA) as it can be seen in Figure 5. The pylons serve to support the axes.

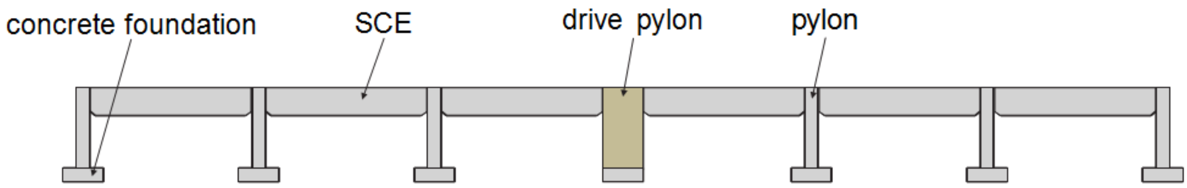


Figure 5: Scheme of solar collector assembly [8]

In commercial parabolic trough power plants, multiple serially connected SCAs form a collector loop. Figure 6 shows a schematic illustration of a collector loop and its connection to the so-called header piping.

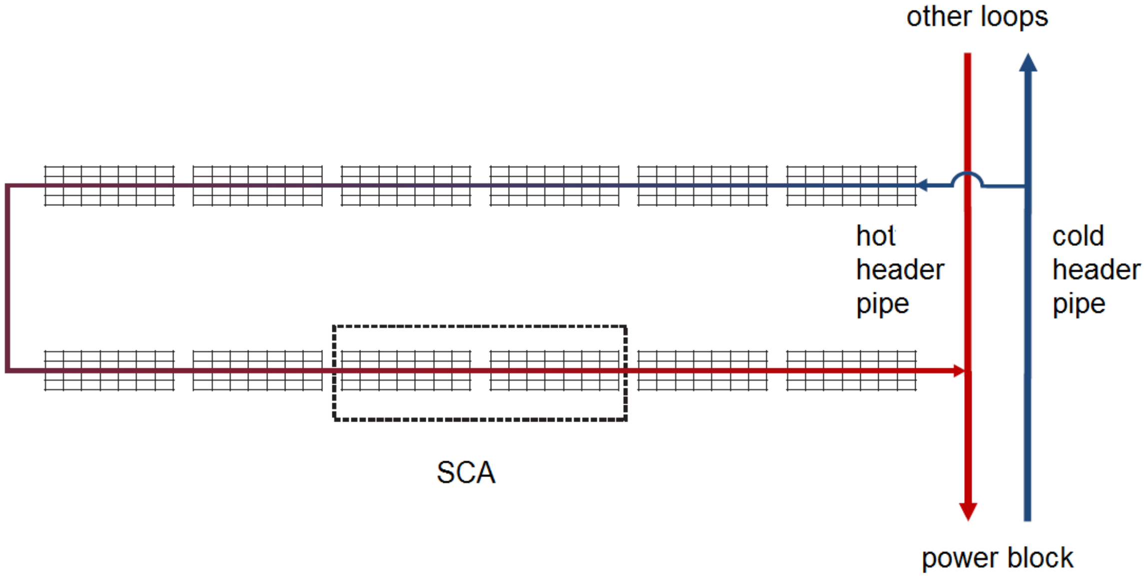


Figure 6: Scheme of collector loop [8]

Figure 7: Noor 1 PTC power plant in Morocco [9]

Figure 7 shows several parabolic troughs at the Noor 1 PTC power plant in Morocco's Ouarzazate province. The plant was connected to the Grid in February 2016 [10].

Except of the heat source, the principal function of a PTC power plant is similar to conventional power plants. By the use of molten salt, heat can be stored at high temperatures. This allows a full-time operation of the power plant, both in times of low radiation and during the night. Heat storage also allows adjusting the electric power generation and outputting according to an order, also called "*dispatchability"*. This leads to a major benefit of PTC power plants with TES, making them an interesting technology on the renewable energy market.

Figure 8 shows the three PTC power plants Andasol 1-3, situated in the province of Granada, Spain. Each of the power plants disposes of an electrical power of 50 MW and thermal energy storage [11].

Figure 8: Arial view of Andasol 1-3 PTC power plants [12]

A more detailed view on concentrated solar power technology and parabolic through power plants is given in *"Chapter 2 – Fundamentals"* of the preceded Master thesis *"Design of a Test Rig and its Testing Methods for Rotation and Expansion Performing Assemblies in Parabolic Trough Collector Power Plants"* by Andreas Plumpe [8].

1.3 REPAs

In order to focus the reflected and concentrated sunlight on the absorber tube the parabolic reflectors must move, therefore usually a one-axes tracking system is used. In common applications the collector axis of rotation is not aligned with the focal line, accompanying the linear, thermal expansion of the heat collecting element has to be compensated. In order to establish a connection between the rotating and expanding HCE and the rigid tubing system, so-called Rotation and Expansion Performing Assemblies (REPAs) are used.

Nowadays there are two competing technologies, so-called Ball Joint Assemblies (BJAs) and Rotary Flex Hose Assemblies (RFHAs). As well as BJAs, RFHAs are insulated to reduce heat losses.

A ball joint assembly consists of three ball joints which compensate for both, rotation and expansion of the solar collector assembly. A ball joint assembly without its insulation can be seen in Figure 9.

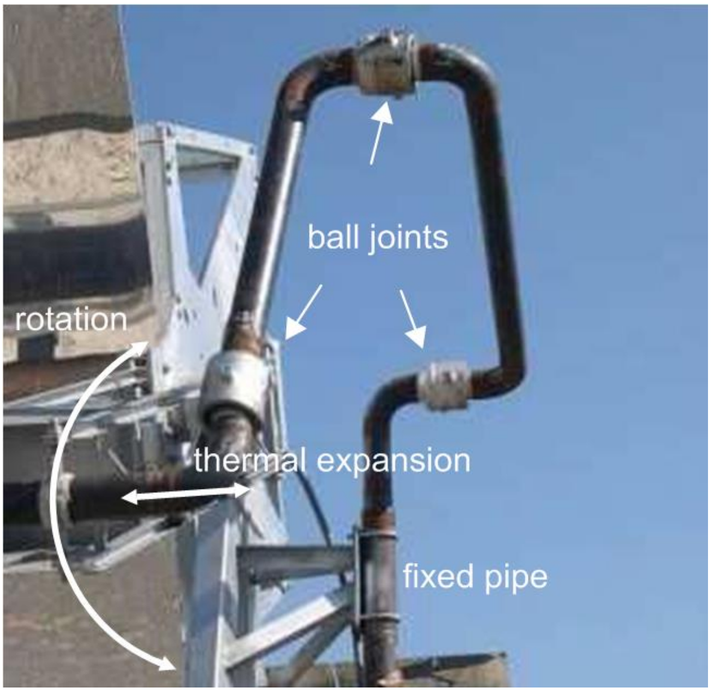


Figure 9: Ball joint assembly (without thermal insulation)

Rotary flex hose assemblies compensate the main part of the rotary motion by the use of a swivel joint. The so-called *torque sword* serves to establish a connection between the rotation axis of the SCA and the swivel joint. A corrugated metal hose provides the additionally needed flexibility to compensate the thermal expansion. Figure 10 shows such an RFHA.

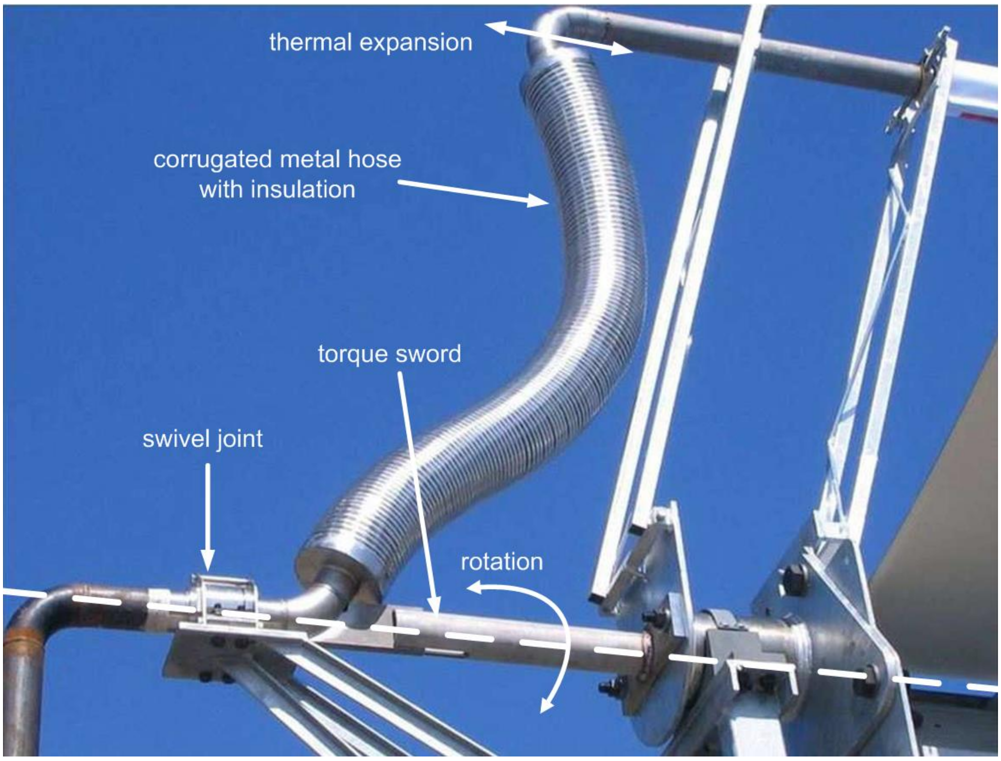


Figure 10: Rotary flex hose assembly

1.4 Motivation for a REPA test rig

In a typical solar field with exemplary 120 Collector-loops, 960 REPAs are installed. The investment sum of this flexible joint assemblies amounts to about one million Euros. [13] REPAs are exposed to high pressures and temperatures, repeated motion, mechanical stress and concentrated sunlight and therefore being highly stressed elements.
A failure of these assemblies leads not only to cost-intensive shot down of the entire affected PTC loop but can also, depending on the used HTF, lead to dangerous situations such as fire and discharge of harmful substances.
A reliable long-term function of these devices is essential for a safe and failure-free operation of the power plant. With the present described test rig, investigations on endurance, life expectancy and failure mechanisms will be executed.

1.5 Plataforma Solar de Almería and German Aerospace Center

The “Plataforma Solar de Almería” is a solar energy investigation center owned and operated by CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas). It was found in the early 1980s and is located in the desert of Tabernas in the Spanish province of Almeria. Solar thermal power components are tested under real exposure conditions on an area of over 100 hectares. [14]
The DLR Institute of Solar Research, played a major role in the construction of the PSA in the early 80s and has been making use of the facility ever since. A permanent delegation of scientists, engineers and several students conduct solar technology testing and development work for the DLR. Figure 11 displays an aerial view of the PSA.

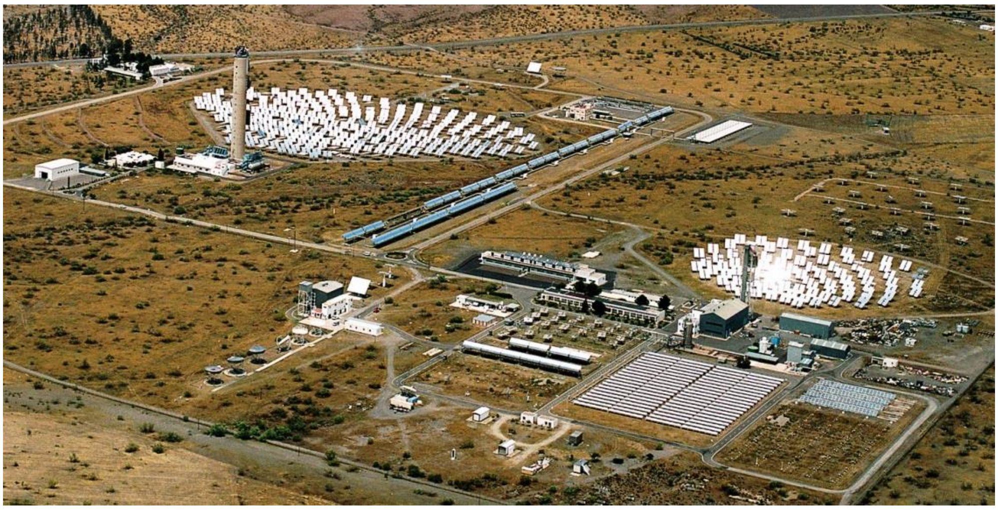


Figure 11: Aerial view of PSA [14]

The present thesis was written at the qualification department of the Institute of Solar Research, member of the German Aerospace Center (DLR).
The qualification department develops measurement techniques which can be used to study and evaluate the key elements of CSP technologies. Hence investigations on individual components and collector systems, their interplay in the system of a power plant, the meteorological conditions and their impact on the system are executed. Furthermore the depart-

ment evaluates the system performance of collectors and solar fields and develops guidelines and standards for testing procedures and quality criteria.
With these measures, possible improvements can be identified and applied to achieve more efficient and cost-effective concentrated solar power technologies.

The REPA project is executed in close collaboration with CIEMAT. Employees of both institutes are working hand in hand together from the design of the test rig to its commissioning and future test application of REPAs at the test rig.

1.6 Demarcation

1.6.1 State of previous work

In the preceded Master thesis „Design of a Test Rig and its Testing Methods for Rotation and Expansion Performing Assemblies in Parabolic Trough Collector Power Plants" [8] ", inter alia, the requirements of a REPA test rig were determined and a design was developed. A concept for the power supply and electronic control was framed. This concept was represented in form of a circuit diagram and an electric cabinet arrangement.

1.6.2 Present work

This bachelor thesis was executed during a three months stay at PSA accompanied by a previous three months internship.
Key activity of the present work is the development of the motion control of the externally designed kinematics unit. This includes the extensive revision of the initial electrical and electronical concept, the design of a SCADA system concept, the development of the PLC code as well as the integration and configuration of sensors and other control hardware.

2 Description of the REPA test rig

The purpose of the test rig is to enable an accelerated, yet realistic, durability test of two serial connected REPAs. Therefore it facilitates the accelerated reproduction of temperatures, pressures, mass flows and mechanical movements through continuous tests according to the cyclic stresses and strains occurring in a solar field.
Therefore the kinematic movement of parabolic troughs, resulting in translation and rotation, is reproduced. Furthermore a HTF circuit generates operating temperatures – and pressures.

As well as tests with Rotary Flex Hose Assemblies (RFHAs) tests with Ball Joint Assemblies (BJAs) are possible. The tests may be conducted with different heat transfer fluids. Additionally to the operating parameters, the mechanical load of the REPAs like breakaway torques are measured and recorded by installed dynamometers. The six channel dynamometer measures each torque and force in three dimensions.
Further application conditions, as a malposition of the swivel joints, can be represented if needed. By this typical damage scenarios can be investigated.

2.1 Design of the test rig

The test rig is subdivided into a kinematics unit and a HTF unit. These two units are connected by the HTF flow- and return pipe but build within two different chambers, displayed in Figure 12 and Figure 13.
To monitor and control the kinematics unit and the HTF unit a Supervisory Control and Data Acquisition (SCADA) system is introduced. The SCADA system is divided into various main areas, further described in chapter 9.

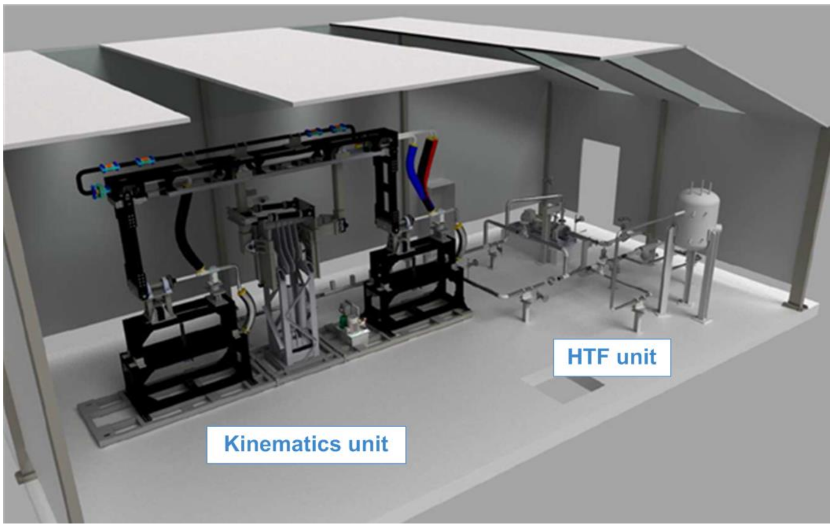


Figure 12: CAD model of the REPA test rig (left: kinematics unit, right: HTF circuit)

Figure 13: Picture of REPA test rig

2.2 HTF unit

The HTF unit heats and circulates the heat transfer fluid through the kinematics unit piping at temperatures up to a maximum of 450° C, pressures up to maximum 40 bar and volume flow rates in the range from about 5 to 60 m^3/h.
Most common, state of art HTFs allow an operating temperature of 400°. New silicon based HTFs are currently tested. These silicon oils will allow an operating temperature of up to 450 °C. The test rig is designed to operate with these new HTFs as well. So the influence on REPAS as well as the general behavior of state of the art and upcoming HTFs can be investigated realistically.

2.3 Kinematic unit

2.3.1 Brief overview of the kinematics unit

The kinematics unit includes two REPAs orientated in the same direction and installed with the identical positioning. This allows for comparison of measurement results between both installed REPAs. The kinematics unit serves to reproduce the rotation- and expansion motion of the simulated collector in an accelerated sequence. Consequently the mechanical mountings and geometries can be adjusted. The kinematics unit core is an "*Euro-Trough Drive pylon*" with a modified hydraulic system moving two swiveling arms which serve to generate the rotational movement. The rotational movement is driven by two cylinders; the mechanical layout is presented in Appendix 14.5. To reproduce translational movement representing thermal expansion, an additional assembly, driven by two hydraulic cylinders is mounted. The kinematics unit was designed by "*IW Maschinenbau GmbH*" after the requirements presented by DLR. A more detailed view on the kinematics unit is given in [8]. Figure 14 illustrates the kinematics unit.

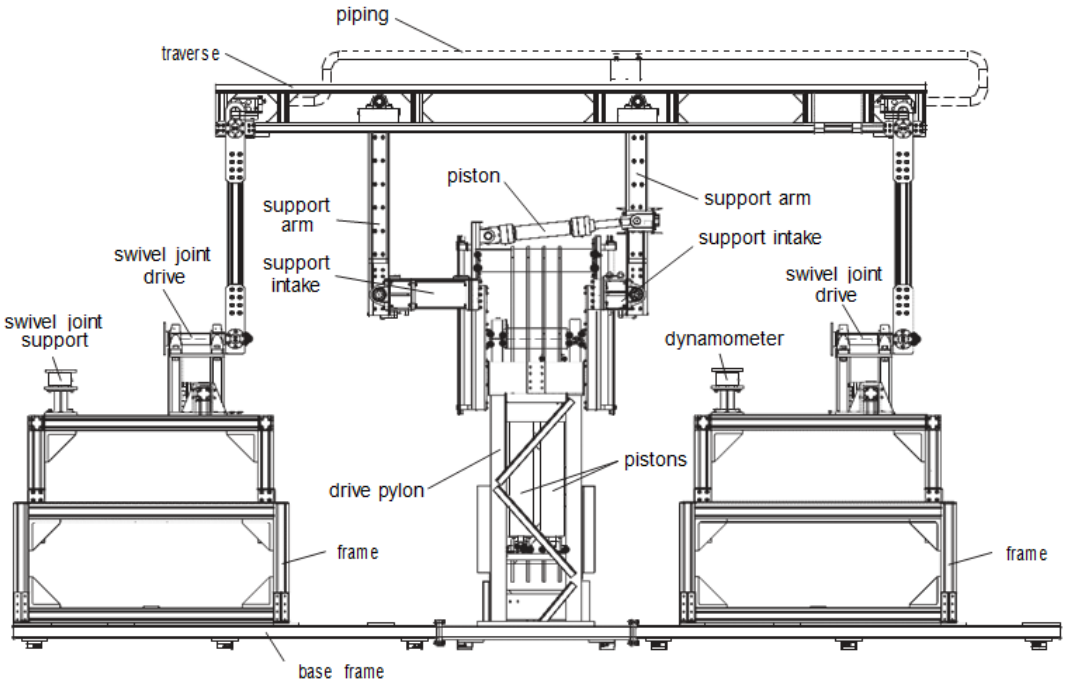


Figure 14: Technical drawing of the kinematics unit

2.3.2 Motions and measurements of the kinematics unit

The kinematics unit was designed to be able to move from 0° to + 45° in the translational axis and from -120° to +90° in the rotation axis, illustrated in Figure 15.

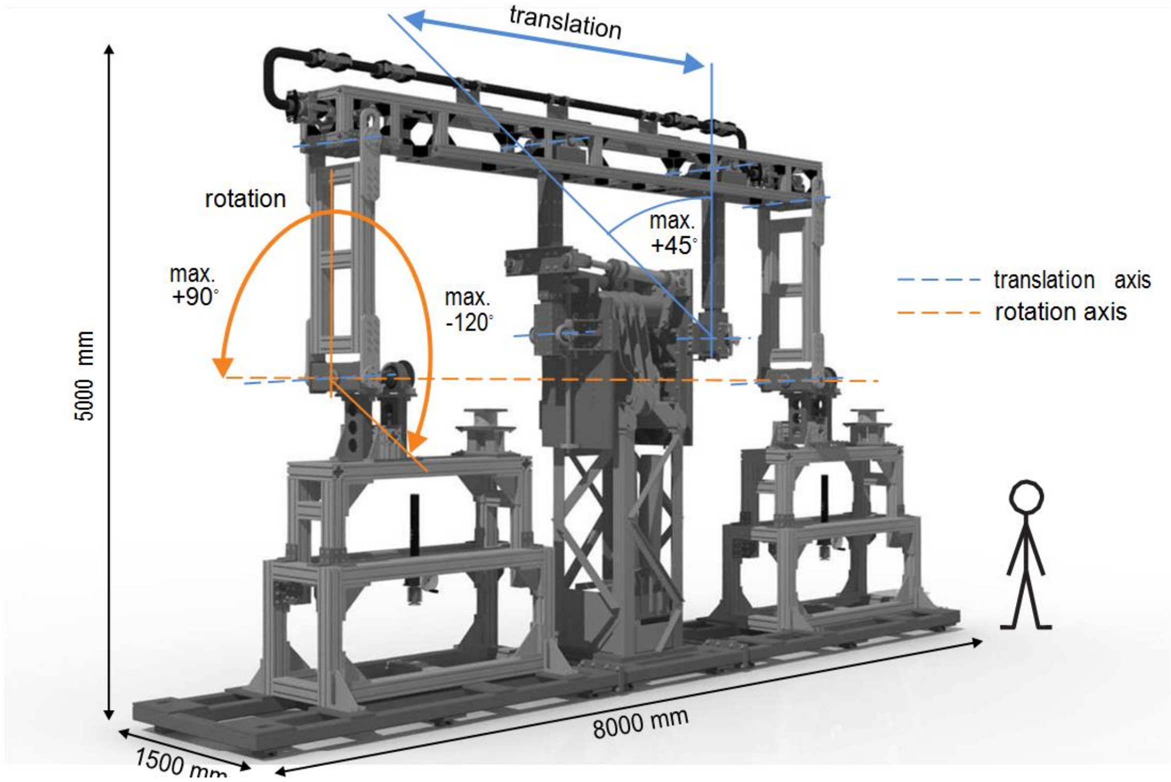


Figure 15: CAD model of kinematics Unit

A magnetic scale sensor was chosen as the measurement system for the rotational position (sensor choice discussed in 8.3). A rotary encoder determines the translation position.
For both, rotation- and translation movement, in sum four, additional end position sensors are installed. These limit switches are represented by a switch flag and an inductive sensor and prevent a motion exceeding the limits of the mechanical structure. The additional measure provides a redundancy, which is necessary to avoid damage on the kinematic structure in case of measurement failure. In chapter 8 further details, on the implementation and types of sensor, are given.

2.4 Hydraulic unit

The hydraulic unit drives the kinematics unit. It contains motors, pumps and valves actuating the hydraulic cylinders and therefore enables the kinematics unit to move. It consists of the hydraulic control unit and external elements. The most hydraulic parts covering control and hydraulic logic functions are summarized by the hydraulic control unit. The hydraulic unit was designed externally by Weber Hydraulik, LOG Hydraulik GmbH. in Figure 16 a photo of the hydraulic unit is presented.

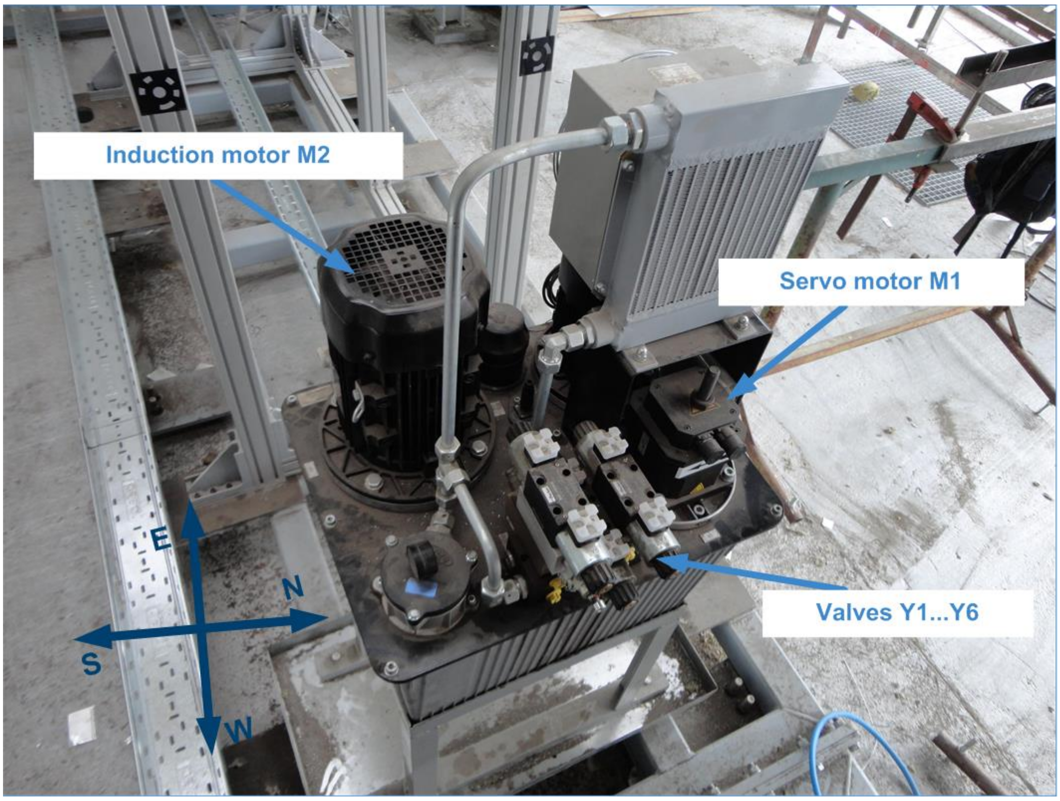


Figure 16: Hydraulic control unit

The core elements of the hydraulic unit are the following:

Rotation:

- Servo motor (M1, driven by servo controller 6SC1) driving gear pump (ELI2-D-7,0-T0-D-N)
- 4/3-control valves
    - Y1 & Y2 actuating cylinder rot.east
    - Y3 & Y4 actuating cylinder rot.west

Translation:

- Induction motor (M2, driven by VFD 7FC1) driving gear pump (ELI2-D-7,0-T0-D-N)
- 4/3-control valves
    - Y5 & Y6 actuating cylinders tran.south and tran.north

Furthermore, additional elements such as a cooling system, relief valves, load retaining valve blocks, load holding valves as well as pressure, temperature and oil level monitoring sensors ensure the correct function of the unit. Since flexible hydraulic hoses interact as a low pass-filter, their use is avoided. Instead stiff tubes are installed to connect the hydraulic control unit with the cylinders. The use of flexible tubes is reduced to a minimum and only inserted where they are implicit needed.

A hydraulic diagram is shown under Appendix 14.2 Hydraulic unit circuit diagram.

The core elements of the hydraulic unit are shown in the simplified schematically sketch of the hydraulic unit Figure 17.

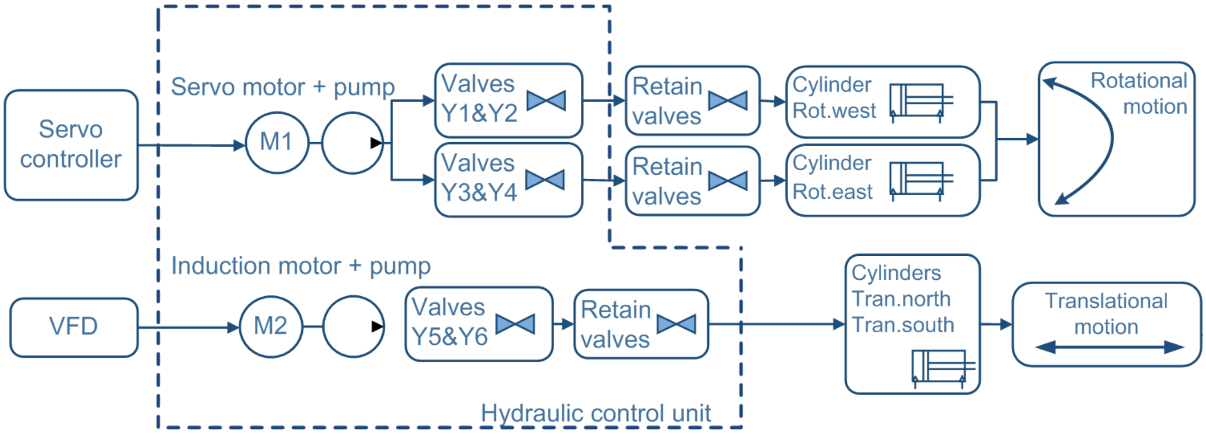


Figure 17: Simplified schematically sketch of the hydraulic unit

3 SCADA system

The term Supervisory Control and Data Acquisition (SCADA) stands for a computer system monitoring and controlling a technical process. It serves to monitor and control the test rig.
Figure 18 displays a sketch of the SCADA system with a focus on its components. On the highest levels stands the Graphical User Interface (GUI) implemented by the software LabVIEW running on a computer. LabVIEW also serves as a platform to gather data coming from the Programmable Logic Controller (PLC) and additional filed devices such as the dynamometer or the monitoring cameras. The Open Platform Communications -server (OPC-server) serves as an interface between the PLC and LabVIEW. As OPC- server the software KEPserverEX of the manufacturer Kepware will be used. Most field devices, sensors and actuators, such as motors, valves, electrical equipment, position and temperature sensors, variable frequency drives and others are connected to the PLC via Input-/Output modules (I/O modules).
The different components are explained in more details in the following chapters of the present thesis.

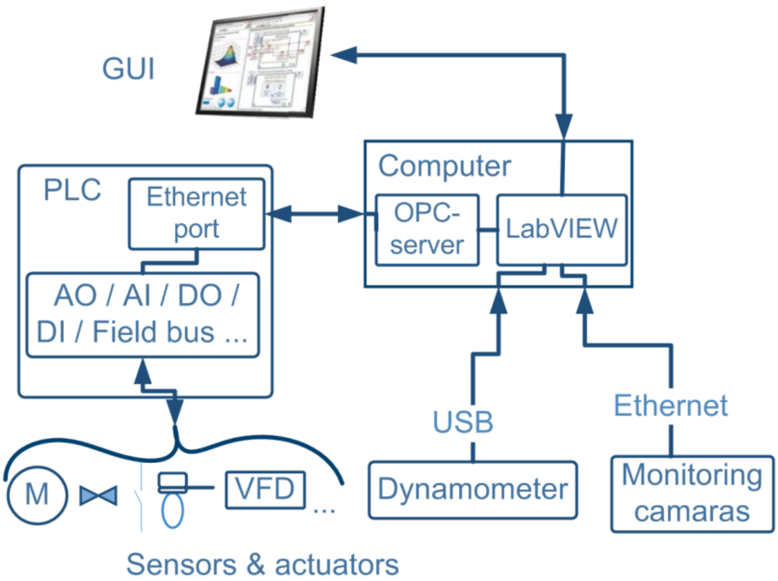


Figure 18: Sketch of SCADA system components

The SCADA system of the present test rig was divided into five main areas (observe system / check status, operate HTF cycle, operate kinematics unit, data acquisition and human-machine interface (HMI). It´s tasks where distributed across the corresponding areas, moreover the responsibilities were assigned to the SCADA subsystems: LabVIEW (LV), PLC and OPC-server.
By Figure 19 an overview of the SCADA main areas and it´s tasks is presented, the responsible subsystems are noted within square brackets ([responsible subsystem]). For the project this is documented in form of an outline with detailed descriptions. An extract of this outline for the operate kinematics area and the motion control task is given in chapter 10.1.1.

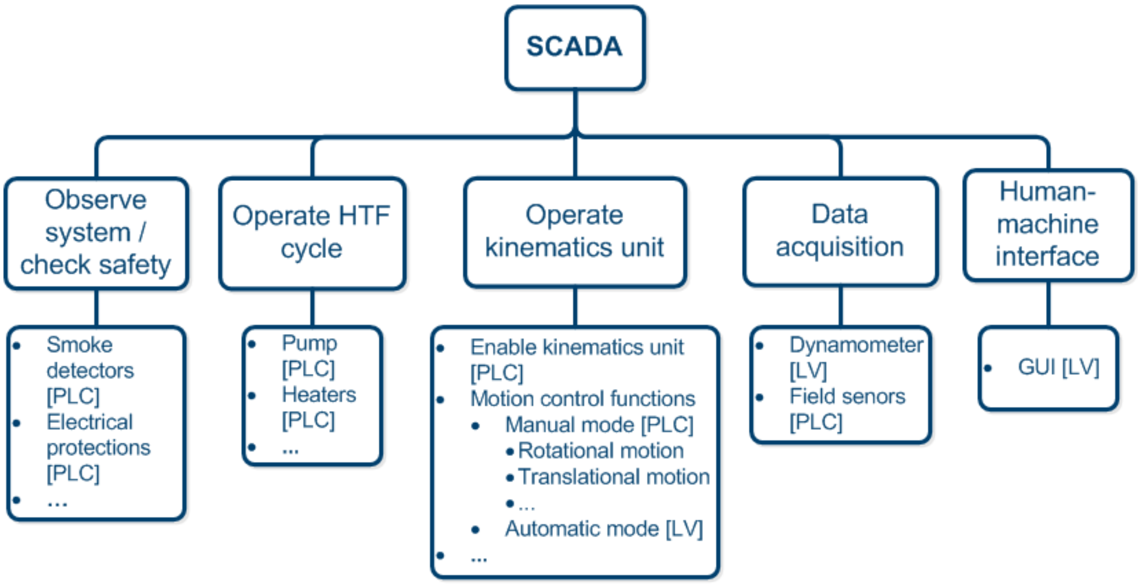


Figure 19: Overview of SCADA main areas and tasks

3.1 LabVIEW

At the PSA LabVIEW is the preferred design platform for data acquisition, instrument control, and automation tasks. One of the benefits of LabVIEW is the graphical programing which allows also users without a programming background a rather fast and intuitive access to generate a program. Another advantage of LabVIEW is the wider support for interfaces to different devices, not only from the manufacturer National Instruments but also from third party providers. Furthermore there exist large libraries for data acquisition, signal generation, mathematics, statistics, signal conditioning, analysis and graphical interfaces which make LabVIEW a suitable tool for many tasks.
As well knowledge and licenses are present, what makes LabVIEW as a first choice for the development of a SCADA system.
LabVIEW is running on an operating system which in this case will be Windows. And here is also the weak spot of a SCADA system based on LabVIEW. The LabVIEW program can only be as stable as the system on which the portal is running on. In general, an operating system (OS) is responsible for managing the hardware resources of a computer and hosting applications that run on the computer. Common operating systems (OS) offer cost efficient access to high performance hardware and are excellent platforms for non-critical measurement and control systems. Such operating systems are designed for a broad range of applications and a comfortable handling. However, common operating systems are not optimized for tasks which require precise timing, strict prioritized or extensive long term operations. To

give an example: A common OS is designed to execute various processes at the same time (multitasking) this is an indispensable feature for a wide range of user applications and provides the opportunity to run different programs and processes in parallel. A down side on this is that a program with a rather low priority can hog the processer power and therefore slow down or even block the execution of a different process with a higher priority. In addition, many common OSs are not designed for static long term operations and therefore occasional system crashes are accepted in favor to other aspects. [15]

3.2 Real-time operating system

A real-time operating system (RTOS) is designed for high-reliability, deterministic performance and a suitable tool for critical applications. This can be especially important in measurement and automation systems where downtime is costly or a program delay could cause a safety hazard. To be considered "real-time", an operating system must have a known maximum time for each of the critical operations that it performs. [15]

3.3 PLC

Various real-time systems are available on the market. So, National Instruments offers real-time systems which are LabVIEW compatible.
A more traditional real-time system is a so-called PLC where PLC stands for “Programmable Logic Controller”.
PLCs where developed in the seventies to replace hard wired relays and timers controlling industrial plants. They are automation controllers and a typical application for real-time systems (also see 11.5). The very basic standard components of a PLC are: a micro processer (µP), memory to store the program and parameters, several in- and outputs for sensors and actuators, often a HMI and an interface for communication. Figure 20 represents the schematical hardware structure of a PLC with power supply, CPU with components such as an integrated fieldbus, and various analog and digital in- and outputs (AI, DI, AO, DO). PLCs are universally applicable and often module based, so they can be suited adequately to the corresponding task. PLCs have been widely adopted as high-reliability automation controllers suitable for harsh environments. These features made them a wide spread mass product.

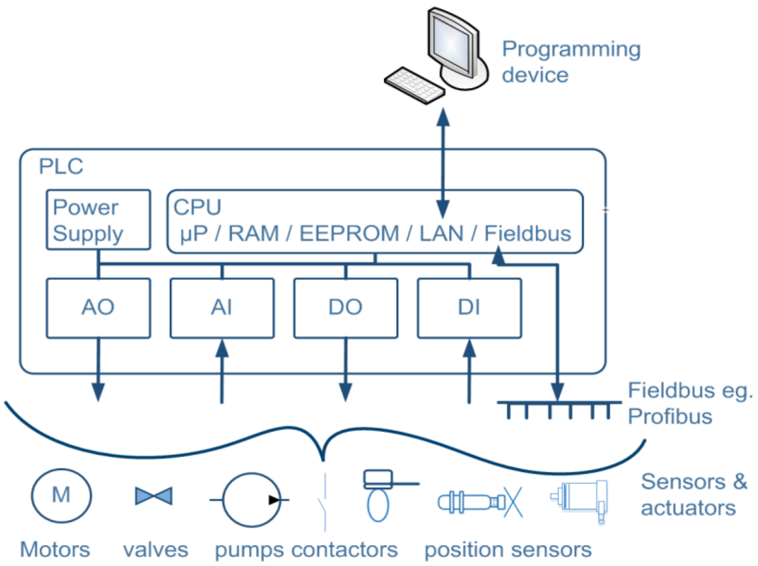


Figure 20: Sketch of a PLC structure [16]

3.4 Automation devices

Besides PLCs, process control systems, motion control systems, microcontroller and PCs are commonly used automation devices. Process control systems are mainly used in process engineering and often consist of multiple control systems, automation devices and interfaces which are connected within a network.
For motion control applications for factory automations special motion control-systems are used. These systems, with very fast cycle times, can control and synchronize variable motors and coordinate motions.
Microcontrollers are often used for smaller applications. They are cheap and have low power consumption. One of their main disadvantage is that they usually have only a few and mostly not standardized interfaces. This comes into effect for the integration of sensors and actuators.
For many applications PC are suitable automation devices where the control algorithm can be written in a high level language such as C or G (G is the language used by LabVIEW). [15] [16]

Other interesting alternative to the above described so-called hard PLCs are slot- and soft-PLCs. Slot-PLCs are plug-in-boards for PCs. By the use of a multi-ported RAM, PLC and PC can access the memory in parallel, what facilitates the data exchange. A soft-PLC is based entirely on software and uses the hardware of a common PC. The communication with field devices can be realized by plug-in-cards. The use of a PC enables access to a wider field of resources and technologies, a higher performance and cost efficient all-in-one-solutions (PLC+HMI). Using an industrial computer with a real-time operating system kernel, the requirements on robustness and reliability can be achieved. [16] [17]

3.5 Comparison LabVIEW versus PLC

Historically LabVIEW had main advantages in data analysis and complex mathematical functions. A PLC was a preferred choice for industrial applications where a stable and highly reliable system was needed. Due to PLCs with continuously increasing computing power and RTOS for LabVIEW applications (such as PACs programmable automation controllers) these boundaries become more and more blurred. [18] [19]

3.6 Why a real-time system is needed?

To control the REPA test rig a real-time system is needed for various reasons. Moreover, both the control of the HTF and the kinematics unit requires a real-time system. Since the HTF unit heats the HTF to high temperatures under high pressure, a malfunction can damage the test rig. The same is true for the kinematics unit; a malfunction or crash of the system could cause an uncontrolled motion and thus damage the mechanical structure or the cylinders.

4 PLC

4.1 Choice of PLC

Due to the above described, it was decided to base the control of the test rig on a PLC. Next to its real-time ability the robustness and long-term stability of a PLC are important factors. The test rig is supposed to run continuously during test periods of three months.

In addition, for the HFT unit a closed-loop control will be applied. Common PLC languages provide pre-build functions for this purpose, which enables an easy and fast implementation.

During the planning process, it was decided to use a SIMATIC S7-300 universal controller from the manufacturer Siemens. The S7-300 is a universal automation system which can be adapted to various kinds of applications, due to its modular concept [20]. The performance power of S7-300 series lies in the middle range of available PLC systems and various systems at the PSA were implemented with these models. Furthermore, by choosing a CPU form the S7-300 series, advantage of a small, onside stock of exiting S7-300 modules can be taken.

4.2 PLC CPU

The CPU 315-2 PN/DP was chosen, as demonstrated in Figure 21 it lies in the middle class of S7-300 CPUs. During the planning process it was assumed, that the CPU performance will be adequate to fulfill the requirements, which is not yet proven. By the integrated PROFIBUS DP interface a PROFIBUS DP network can be built easily. Figure 21 illustrates the differences between the six performance classes of the S7-300 CPUs (firmware V3.x and higher).

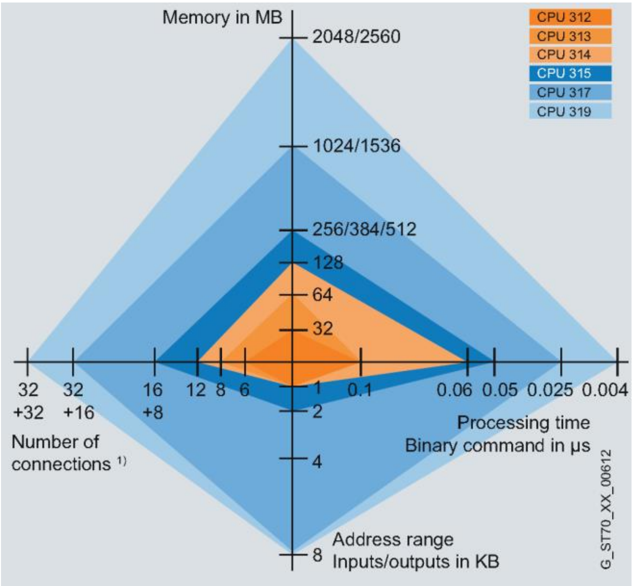


Figure 21: Overview of S7-300 CPU performance classes [20]

"1) Connections stand for internal resources of the CPU […]. The standard bus communication […] do not require connections. […]." [20]

4.3 PLC components

The PLC S7-300 is a modular system. The CPU could be described to be the head of the system and determines the computing performance. To make the PLC suitable for different tasks, a wide variety of modules are available. The most common modules are different analog and digital in- and outputs. In addition, there are technologies- and other function modules, such as counters or interfaces. To know which modules are needed a signal list was created. It contains all sensors and actors which interact with the PLC. Also it displays their most important properties, like the type of signal they use, are listed. The signal list can be found in appendix 14.12

For the test rig a total of about 130 PLC external signals were gathered. To leads to the following PLC configuration: Five analog inputs modules monitoring sensors like thermocouples and RTDs or signals transmitted by an analog signal from a transducer. The two digital input modules receive mainly signals from auxiliary contacts or sensors detecting a binary status, like the limit switches. The two analog outputs are used to output set points for equipment such as the VFDs or electrical valves. By the digital outputs, binary valves and electrical equipment such as contactors and relays are controlled. Furthermore the enabling of power electronic elements such as VFD and servo controller is controlled via digital outputs. The FM 350-1 counter module is needed for the integration of the magnetic scale sensor (see 8.3.1). The CPU 315 allows a maximum of 8 modules on one rack, to expand the PLC by a second rack the modules IM 360 and IM 361 are used. Figure 22 displays the PLC configuration with power supply, CPU, expansion interfaces, counter module and various digital and analog in- and outputs.

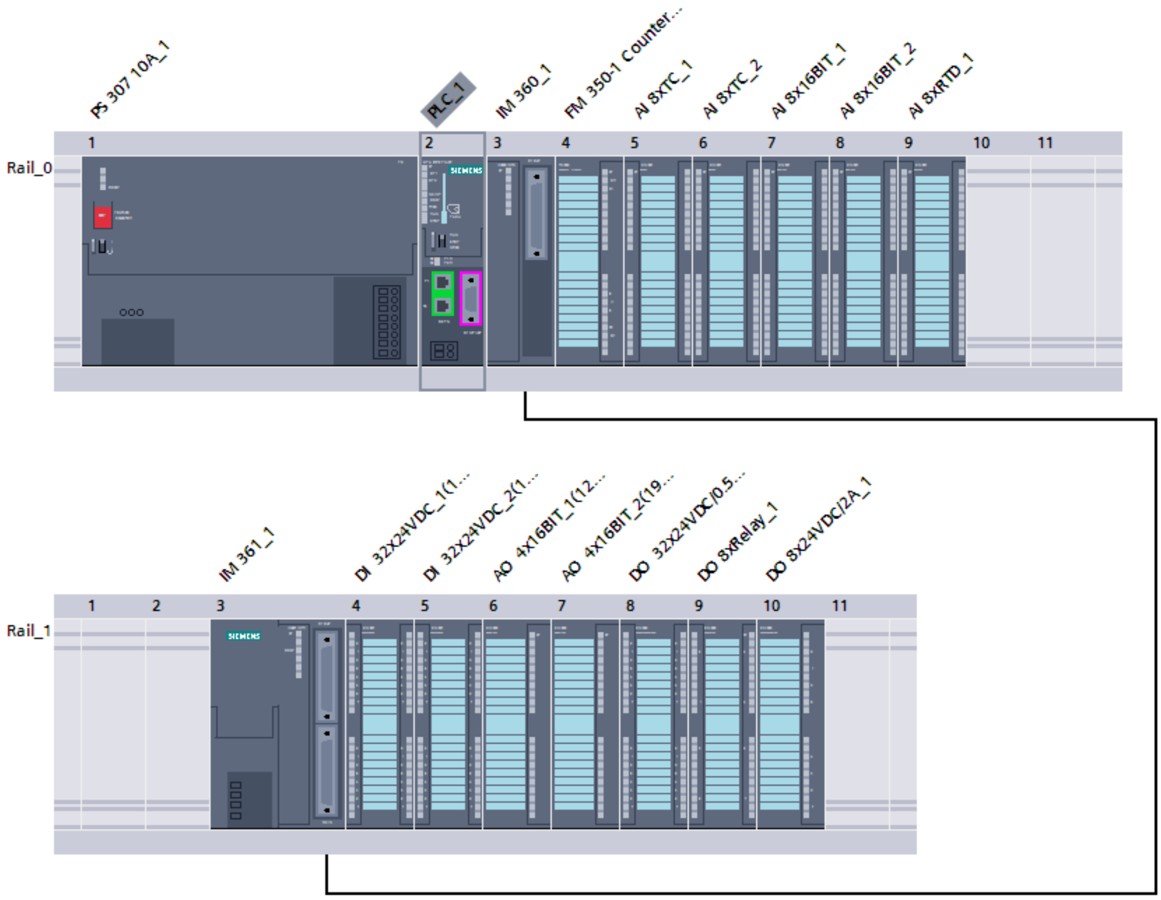


Figure 22: PLC configuration

For the integration of the absolute rotary encoder a PROFIBUS-DP network was created, demonstrated in Figure 23.

Figure 23: PROFIBUS DP network

5 Electrical cabinets

In order to provide the test rig components with electricity the so-called power cabinet was designed. It is responsible for the distribution of the electric energy and therefore contains equipment such as switches, contactors and protections. Furthermore some control equipment with high power consumption, such as two variable frequency drives and a servo controller are placed in the upper part of the power cabinet. Aside from the power cabinet the so-called control cabinet was designed, it contains mainly the equipment responsible for the PLC control including the connections for the field sensors, the 24 V power supply and the distribution of the uninterruptible power supply (UPS) voltage.
The cables are distributed to the field by two separated cable trays. This separation is necessary to avoid electromagnetic distortions of signals coming from the power cables. To get a clear overview across the electrical equipment and connections an electrical circuit diagram was created, see appendix 14.14. In Figure 24 both cabinets next to each other and the cable trays are displayed.

Figure 24: Electric cabinets

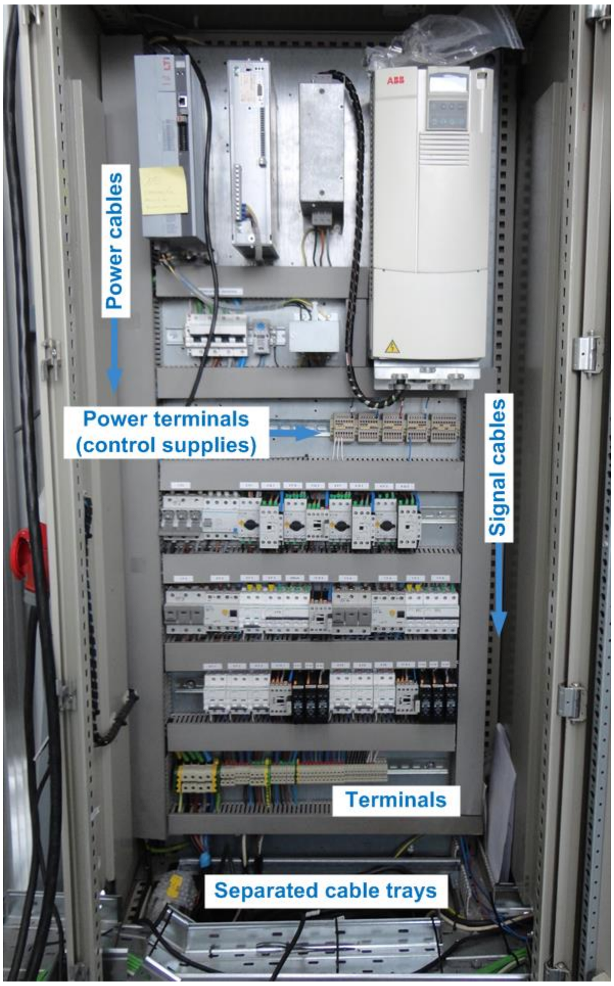


Figure 25: Power cabinet

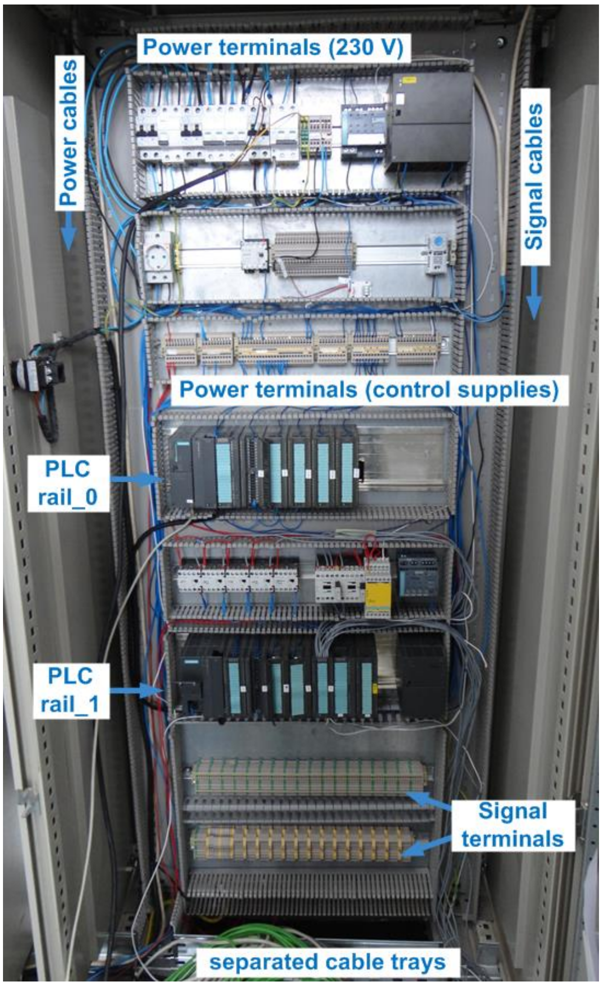


Figure 26: Control cabinet

Figure 25 displays the power cabinet and Figure 26 the control cabinet. Next to the terminals, the cable routing concept is presented. In order to avoid malfunctions of equipment through electromagnetic disturbances, power and signal cables are routed separately. Where a minimum distance of 20 cm between signal- and power cables can´t be complied, these are separated by a metal wall.

6 Test rig motions

6.1 Fundamentals and definitions of the test rig motions

6.1.1 Definition of translation angle θ

As mentioned in 2.3 during the planning process the test rig was specified to be able to move on the translational axis in a range of 45°. The position is described by the translation angle θ. This angle is measured between the drive pylon arms and the plane perpendicular to the rotation axis. It is not yet known if the mechanical constructions and the drive elements (such as the cylinder) will permit this motion. At the current stage a theoretical possible motion in the range of – 19° until + 28° is expected. Since the currently installed REPAs normally operate in a range of θ = [-6°,17°] this motion would be sufficient.

6.1.2 Definition of rotation angle φ

The position in the rotation axis is described by the rotation angle φ. This angle is measured around the rotation axis, whereby the reference point (φ = 0°) sits on a vertical line passing through the rotation axis. More specific, it is the angle inside a plane, perpendicular to the rotation axis, measured between the traverse and a vertical line seen from the rotation axis. The vertical position (φ = 0°) is also called rest position. The lowest position (φ = -120°) is called stow position and the highest position (φ = 90°) is called end position.

Since the mechanical constructions aren´t finished yet, it is not known if these limits will be achieved. However, the ranges described here are taken as a base for the development of the motion control system.

6.2 Requirements on the test rig motion

In order to design a suitable motion control, it needs to be clear which specifications have to be fulfilled by the control.
The following requirements were derived or taken over from preceded investigations. Many are explained further, within this thesis, later on but listed here to provide an overview.

6.2.1 Operational and environmental conditions

- Continuous operation during test campaign with a one- to three-month period
- Roofed, outdoor, desert like ambient, rain temporary possible
- Environmental temperatures: -5 to 45 °C

6.2.2 Requirements on the rotational drive

- Separate actuation of two hydraulic cylinders
- Maximum moving speed: about 10 mm/s
- Measurement of the angle between -120° and +90° (range 210°)
- Prevention of exceeding the maximum angles to avoid damaging the mechanical structure
- Continuous and stepwise movement must be possible (step width down to ≤0.25°)

6.2.3 Requirements on the translational drive

- Simultaneous actuation of two parallel hydraulic cylinders
- Maximum moving speed: about 30 mm/s
- Adjustable speed
- Measurement of the angles within a range of 45°
- Prevention of exceeding the maximum angles to avoid damaging the mechanical structure
- Continuous movement independent from rotational drive

6.3 Realization of test rig motions

Whereas the realization of the translational motion is straight forward and can be executed by retracting or extending the both cylinders simultaneously, the realization of the rotational motion needs further considerations.

6.3.1 Translational motion

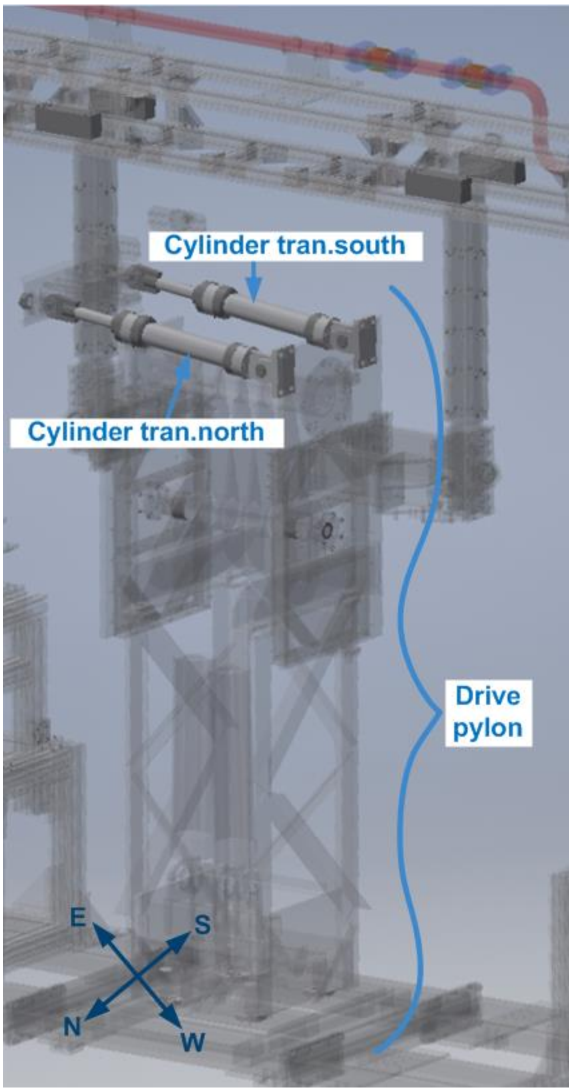


Figure 27: Drive pylon with highlighted translation cylinders

As mentioned above the translational motion is executed through parallel motion of the two cylinders named tran.south and tran.north. The positioning of the valves (Y5 & Y6) determines the direction of the movement.

Table 1 shows the valve positioning and resulting movement of the translational cylinders. If both valves are not activated the load retaining valves prevent a cylinder movement.

Whereby the pressure is built up by a hydraulic pump, driven by an induction motor (M2) – variable-frequency drive (VFD) combination. The use of a VFD allows the regulation of the speed with which the cylinders move and therefore the speed of the translational motion. The system was designed to cover an area of 45° by one stroke within 15 s. Hence the resulting angular velocity of the translational motion is: $\omega_{\theta\,testrig} = 3°/s$. Due to differences between the design and the manufactured structure the resulting parameters may differ. This will be investigated further during the building and commissioning process, carried out subsequently to this thesis.

Figure 27 presents the drive pylon and the highlighted translation cylinders in the CAD model.

Table 1: Valve positioning translational motion

Cylinders tran.south & tran.north		
Valve / tag	Extend	Retract
Y5 / PY-CI-05-W	0	1
Y6 / PY-CI-06-W	1	0

6.3.2 Rotational motion

In general, the rotational motion follows the same principles as the translational motion. But in order to generate a rotational motion the two cylinders must operate disparate to each other.

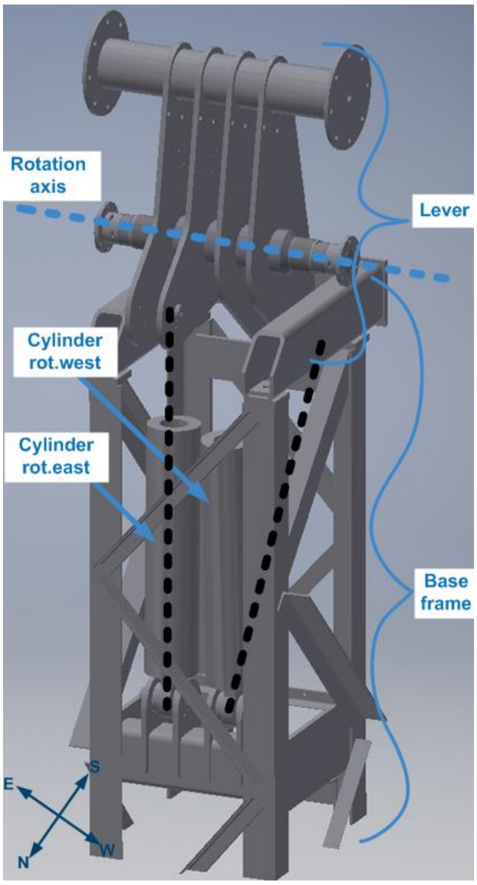


Figure 28: Drive pylon base frame and lever

The drive pylon consists of the base frame and head. The head is the upper part of the drive pylon and describes the unit of frame, lever and end plates.

Figure 28 shows the drive pylon´s base frame and lever as well as the two rotation cylinders. The upper frame and the end plates are omitted in this presentation to put the focus on the parts generating the rotational motion (cylinders and lever). The black dashed lines show the cylinder alignment needed at the presented lever position.

Technical drawings, figures and photos of the drive pylon are shown in appendix 14.5.

One of the requirements of the rotational motion is to be able to execute steps ≤ 0.25°. To achieve such small increments a servo motor is used to drive the hydraulic pump. Since the hydraulic valves need about 100 to 150 ms to open or close, they will remain in their position and the motion will be realized by actuating the servo motor. A servo motor is used because of its high starting torque and easy control.

Table 2 and Table 3 show the valve´s positions and corresponding motion directions of the titled cylinders rot.west and rot.east.

Table 2: Valve positioning cylinder rot.east

Cylinder rot.east		
Valve / tag	Extend	Retract
Y1 / PY-CI-01-W	0	1
Y2 / PY-CI-02-W	1	0

Table 3: Valve positioning cylinder rot.west

Cylinder rot.west		
Valve / tag	Extend	Retract
Y3 / PY-CI-03-W	0	1
Y4 / PY-CI-04-W	1	0

With data from the CAD model, the behavior of the drive-pylon was investigated. Therefore, a geometrical analysis with the help of the software “MATLAB” was performed. More precisely, the changes of length of both cylinders needed in order to create a rotational motion around the centered axis were determined. The change of cylinder length in dependence of the rotation angle phi is demonstrated in Figure 29 and Figure 30.

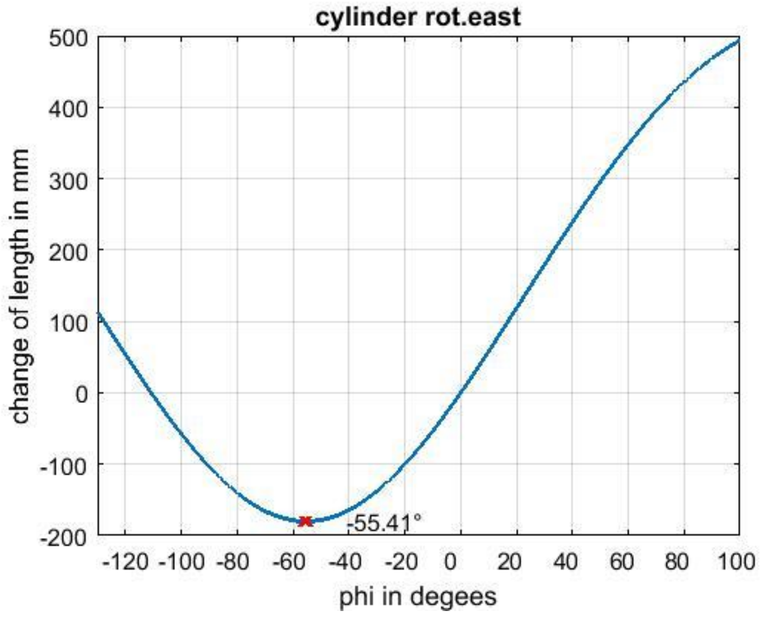


Figure 29: Cylinder rot.east change of length over angle phi

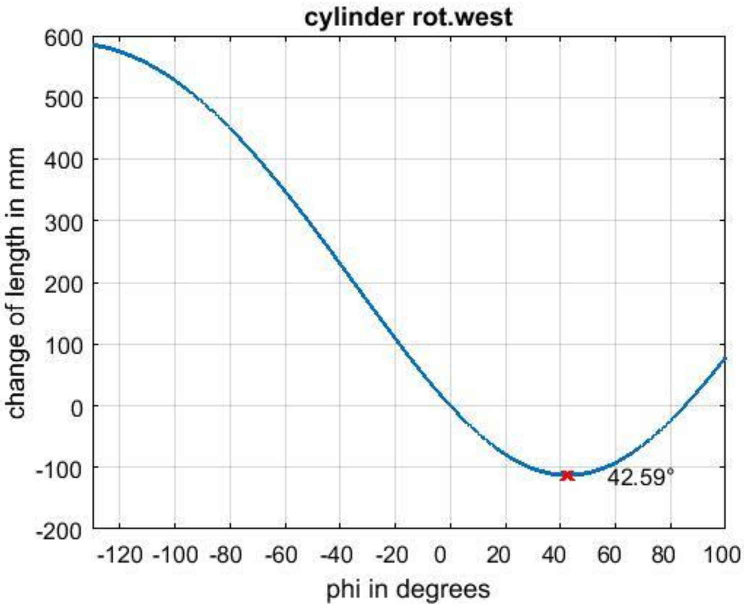


Figure 30: Cylinder rot.west change of length over angle phi

During the above mentioned analysis, the necessity of three areas of different cylinder movement combinations were observed. Furthermore, the critical angles (CA2 and CA3) which define the boundaries between these areas were evaluated. The following angles were found.

Critical angles (CA) for cylinder movements:

CA1: -120° end position negative
CA2: ~ -52 ° change of cylinder “rot-east” (shortest point)
CA3: ~ + 42° change of cylinder “rot-west” (shortest point)
CA4: + 90° end position positive

These findings yield to the areas and corresponding cylinder movement presented in Table 4

Table 4: Areas of cylinder motion to create a rotational motion

Area	Angles	cylinder	Positive movement		Negative movement	
			Rot.-east	Rot.-west	Rot.-east	Rot.-west
CA1 to CA2	-120° … -52°		Retract	Retract	Extend	Extend
CA2 to CA3	-52°… +42°		Extend	Retract	Retract	Extend
CA3 to CA4	+42°…+90°		Extend	Extend	Retract	Retract

Due to deviations from the real existing system to its model, the real critical angles are expected to differ from the calculated angles. The real angles must be found during the commissioning of the kinematic unit by experiments. (Therefore, a special “debug mode” enabling independent manual cylinder motion is implied in the motion control program, see 10.1.1)

7 Motion control system

The previous described requirements and solutions led to the motion control system, schematically described in Figure 31. In the following chapters the different elements, such as the position measurement (see 8) and the implemented functions (see 10), are described in more detail.

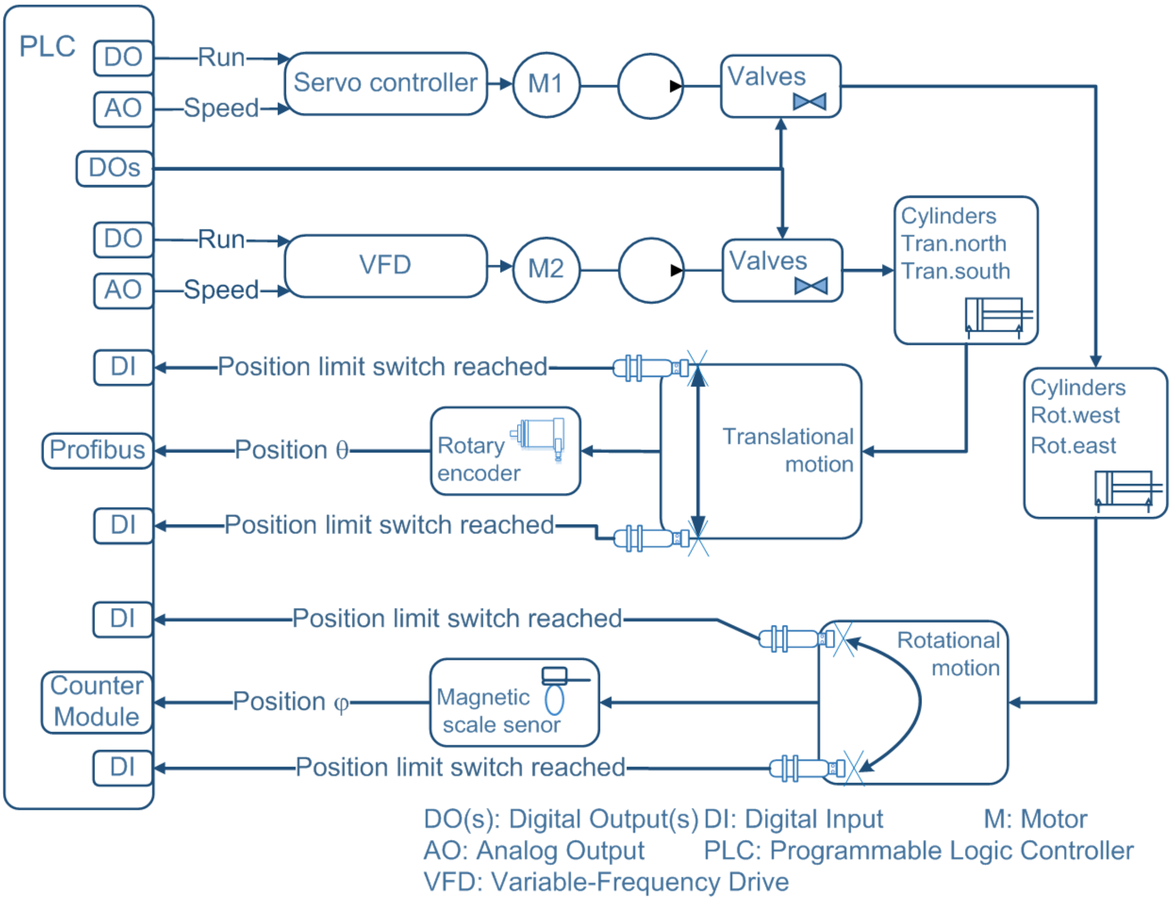


Figure 31: Simplified schematic sketch of motion control system

8 Position measurements

As described under 2.3.2 the motions of the test-rig are monitored by various sensors. While the rotation angle φ is measured using a magnetic scale position sensor, the translation angle θ is measured using an absolute rotary encoder. Additionally four limit switches are implemented as a redundant measure to avoid a motion exceeding the mechanical limits. In Figure 32 the position of the different sensors is shown. It also provides a visualization of the sensors in form of a CAD model.

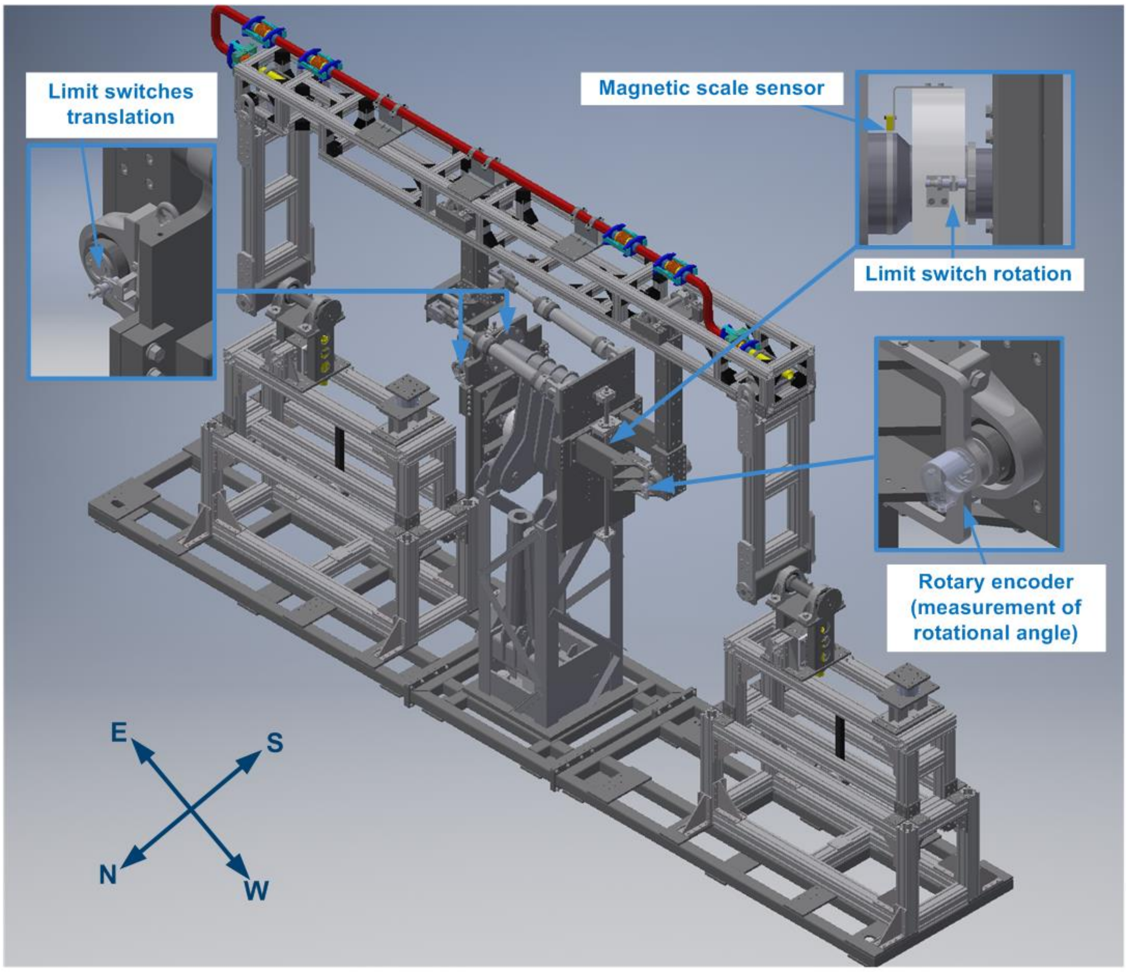


Figure 32: Position and visualization of motion control sensors in CAD model

8.1 Limit switches

As limit switches, inductive proximity switches from the manufacturer BALLUFF are used. A flag is mounted in a fixed position on the axis. Since the switches are declared as normally closed, they will switch from a high to a low status as soon as the distance between the flag and the sensor goes below a certain value. Figure 33 shows one of the two limit switches on the roational axis.

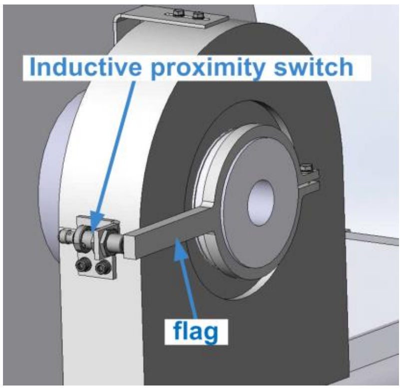


Figure 33: One limit switch on rotation axis

The limit switches are connected to the PLC by digital inputs. To check the performance a function test of the limit switches was executed, the results are presented in Table 5.

Table 5: Inductive limit switch function test

Inductive limit switch				**Date:**	**October 05th 2016**	
Manufacturer:	**Balluff**					
Type:	**BES M12MI-POC40B-S04G**					
Sensor	**Tag**	**Module**	**Address**	**Signal in relation to rated operating distance (4 mm)**		**Status**
				Within	**Beyond**	
rotation negative	ZS-CI-01-W	14	DI 6.4	0	1	OK
rotation positive	ZS-CI-02-W	14	DI 6.5	0	1	OK
translation negative	ZS-CI-04-W	14	DI 6.6	0	1	OK
translation positive	ZS-CI-05-W	14	DI 6.7	0	1	OK

8.2 Measurement of translation

8.2.1 Choice of sensor

The angle of the translational motion theta (θ) is measured by an absolute rotary encoder. During the process of configuring and testing the sensors it was noticed that the beforehand bought rotary encoder is a multi-turn encoder and not a single turn encoder as expected. The multi turn encoder had a maximum measurement range of 64 turns and therefore a coarse resolution. The encoder was meant to be connected to the PLC system via a 4-20 mA signal and offered the opportunity to adjust the range of the DA-converter down to 2 turns. But still the resolution of the measurement system resulted to be about 1° and therefore not suitable for the desired application.

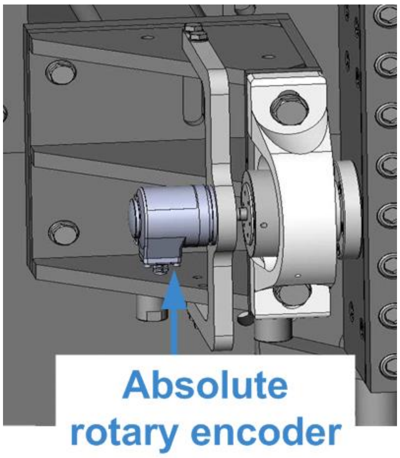


Figure 34: Absolute rotary encoder in CAD model

Figure 35: Picture of absolute rotary encoder

Due to the necessity of buying a new encoder, different encoder types and technologies were reviewed. The use of an analog 4 – 20 mA interface has the advantage of an easy implementation in the existing PLC system but the disadvantage of additionally uncertainties through the conversion to an analog signal, the measurement uncertainty of the PLC analog input module and the analog-to-digital conversion. This fact led to an insufficient measurement accuracy of the angle measurement system for the inspected analog rotary encoders. So, other technologies where considered and inspected under the aspects of measurement accuracy, cost and availability. Because of outer circumstances the encoder had to be bought and paid within a short time frame. The search led to a PROFIBUS rotary encoder. The disadvantage is that a PROFIBUS network needs to be implemented for this sensor but since the CPU has an integrated PROFIBUS -DP interface this inconvenience can be accepted considering the advantages. The main advantage of the chosen encoder, among its short term availability, is the resulting measurement accuracy. The encoder itself has a tolerance of 2 LSB with a 16 bit resolution which in our case results in a measurement accuracy of 0.011° (derivation in 14.7.2). Due to the use of a digital signal no further significant uncertainties are caused by the signal transmission or conversion.

8.2.2 Absolute rotary encoder function test

To verify a correct integration and function of the absolute rotary encoder a brief function test was performed. The value was checked online at different angles whereby a triangle served as reference. The result is shown in Table 6: Rotary encoder function test

Table 6: Rotary encoder function test

Rotary encoder function test	Value	Status
Date: **November 30th 2016**	-170°	OK
	-90°	OK
	0	OK
Variable:	90°	OK
"ZQ-TRA-01-actual-angle"	+170°	OK

8.3 Measurement of rotation

The position of the traverse on the rotation axis is determined by measuring the rotation angle. This angle φ is measured by a system consisting of a “POSIMAG magnetic scale sensor” of the manufacturer “ASM” and a “SIEMENS SIMATIC S7-300 FM350-1 Counter module”. The “POSIMAG®” is a non-contact, high resolution magnetic position measuring system. It consists of a magnetic measuring strip and a non-contact magnetoresistive scanning head. The magnetic measuring strip is periodically magnetized with magnetic north and south poles. To capture a position the magnetoresistive sensor head samples sinusoidal magnetic fields above the magnetic strip. The FM 350-1 counter module counts these samples. Since the distance between the magnetic south- and north poles is known, the number of counted steps represents the covered distance. Figure 36 visualizes the functional principal of the magnetic scale sensor.

The magnetic scale sensor is an incremental system. By these means only the covered distance is measured and the absolute position is unknown in the first place. In order to know the absolute position a reference point is needed. This point is implied by an additional magnetized area on the magnetic measuring strip. Every time the sensor passes this reference point the counter value is set to zero. The position of the reference mark is known and together with the known distance, the absolute position can be calculated.

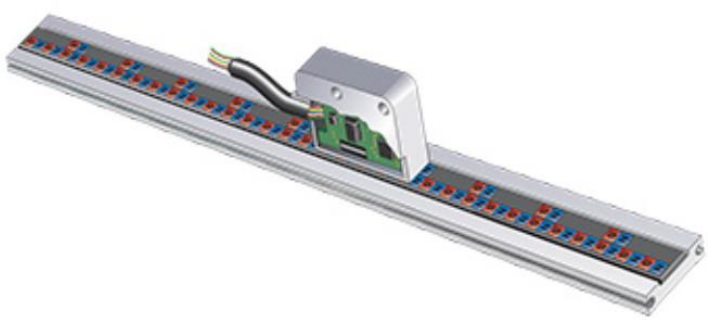


Figure 36: Visualization of magnetic scale functional principal

8.3.1 Integration of the magnetic scale sensor

The magnetic scale sensor can output values with a frequency of 20 kHz. The value of a normal digital PLC input is only scanned once per CPU cycle. The CPU cycle time can vary but can't be faster than 1 ms (1 kHz) and is expected to be in the range of several ten to hundred milliseconds (equivalent to a frequency with a three to two digits Hertz value). For this purpose S7 CPUs which are designed for motion control task come with integrated "fast digital inputs". The present CPU 315-2 PN/DP does not offer such fast inputs. Hence an additional counter module is needed to integrate the magnetic scale sensor. The counter module FM 350-1 was chosen for this purpose. In order to be able to read out the counter value, a memory address must be assigned and a data interface must be created. Furthermore it is necessary to initialize the counter parameters. Such parameters are for example enable up and down counting directions or zero loading at 0-mark passing. This is executed after each complete restart within OB100. The communication between CPU and counter module is implemented by the use of the function COUNTER MODULE CONTROL (CNT_CTL1). The conversation from counter steps into degrees is done by a multiplication. To be able to compensate an offset resulting from a deviation of the zero mark position and the real zero angle position an offset variable "ZU-ROT-03-offset" is introduced.

8.3.2 Retain counter value

The sensor itself has no memory and in case of a power loss neither the relative nor the absolute position is known. For this reason the value is stored within the PLC CPU retain memory. Due to the experience of the instrumentation department, for drive pylon applications it is sufficient to save the position value at least 8 to 16 times per second, depending on the dynamic of the system.

In case of a power failure that cannot be compensated by the buffers a restart of the PLC is necessary. As a default the start value of the counter will be assigned to be zero. With other words the actual counter value and so the knowledge of the position in the rotation axis is lost. If the position of the drive is unknown, it is not possible to generate a rotation without the chances of causing damage to the mechanical structure or the drive itself (see 6.3.2). Consequently the loss of the position value must be avoided. This issue is treated by storing the actual counter value continuously within the retentive memory of the CPU each cycle. In case of a restart a trigger flag is set within OB100. If this trigger flag is set, the last stored counter value is loaded from the CPU retain memory into the counter module memory, within the first executed main (OB1) cycle. Due to the fact that the last stored value might differ within a small range from the actual position the drive has to be moved until it passes the zero reference mark to avoid errors in the rotation angle measurement.

8.3.3 Applicability of the magnetic scale sensor

During the planning process this sensor was favored over the use of an inclinometer as often used in many PTC plants. Using a magnetic scale sensor a better accuracy can be achieved (see 8.3.6). Due to the poor accessibility of the rotation axis, the use of an absolute rotary encoder requires a rather big mechanical effort.

The main application of magnetic scales is the measurement of linear positions. Even so, it is also possible to measure an angle by attaching the measuring strip on a cylindrical surface. For an angular measurement the manufacturer datasheet recommends to glue the magnetic tape on a surface with a minimum radius of 100 mm. In our case the radius is only about 80 mm. Upon request, the manufacturer stated a possible damage to the magnetic strip, if the recommended minimum radius is undercut. Nonetheless, experiments showed that the function of the magnetic scale sensor is not affected using a radius of about 80 mm. Additionally long term experience of the PSA instrumentation department verifies an impeccable function of the ASM POSIMAG magnetic scale, even with a bending radius of less than 80 mm. Figure 37 displays the magnetic scale sensor on the CAD model. Figure 38 shows a photo of a magnetic scale sensor mounted at a PTC application at the PSA.

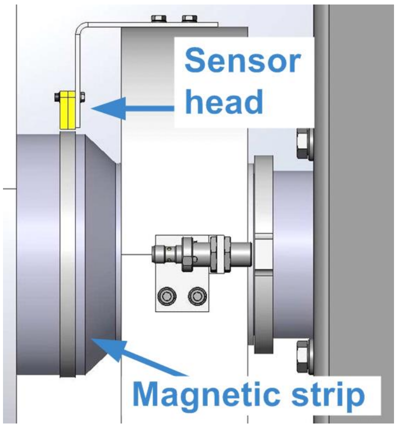


Figure 37: Magnetic scale sensor in CAD model

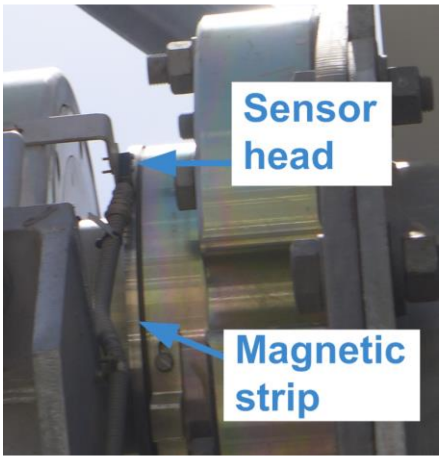


Figure 38: Magnetic scale sensor at PSA

8.3.4 Estimation of rotation angle measurement system tolerance

To get a feeling of the accuracy of the rotational position measurement system its tolerance is estimated. Initially it has to be distinguished between systematic deviations that can be corrected and such which cannot.
The fact that the circumference of the axis, on which the magnetic stripe is glued on, is expected to slightly differ from the initially assumed value, leads to an expected deviation. Also it is considered impossible to glue the magnetic strip in such a way that the reference mark is positioned exactly at the 0° position. Furthermore the reference mark itself has a tolerance of ± 1 mm. But all this errors fall in the category of correctable errors.
After the mounting is finished, a photogrammetry has to be performed to verify a correct axis alignment. With the photogrammetry results, correction factors will be determined to update the program code. Therefore the first kind of errors can be neglected for the treatment of the measurement system tolerance.

Not all deviations or tolerances of the second type are given but with a worst case calculation of the influence of the ones that are given, an estimation of the resulting tolerance of the rotation angle measurement system can be made. The repeat precision and linearity of the "POSIMAG magnetic scale sensor" are given in its datasheet. The precision is ± 1 digit, the linearity 15 µm ± 40 µm/m (both for the sensor with mag. scale PMIB3). Assuming a circumference of 500 mm a worst case estimation leads to a measurement system tolerance of: ±(0.018° + 0.004 % of the measured value) ,(derivation in 14.9.1).

8.3.5 Magnetic scale function test

To verify a correct integration and function of the magnetic scale position sensor a brief function test was performed. Therefor the magnetic scale was put on a tube with a circumference of 50 cm. The value of the variable "ZQ-ROT-01-actual-angle" was checked online at different angles whereby a triangle served as reference. The result is shown in Table 7.

Table 7: Magnetic scale function test

Magnetic scale sensor function test	Value	Status
Date: **October 06th 2016** **Variable:** **"ZQ-ROT-01-actual-angle"**	-220°	OK
	-180°	OK
	-90°	OK
	0°	OK
	+45°	OK
	+100°	OK

8.3.6 Comparison with inclinometer (in respect to drive pylon damage)

In power plant applications, the rotation angle is often measured by an inclinometer. These inclinometers commonly provide an accuracy of about ± 0.1° [21] [22] [23].

With this accuracy a save motion without drive pylon damage trough imprecise motion control is achieved. As shown in 8.3.4, the angle measurement system of the test rig provides a better accuracy. By this it can be assumed the positioning and measurement of the angles are accurate enough to avoid a drive pylon damage trough uncertainty of the rotation angle measurement.

9 PLC Programming

9.1 Naming convention of variables and signal list

The variables are named taking into account the PSA instrumentation nomenclature.
A copy of the PSA instrumentation nomenclature is shown under Appendix 15.11
The first two to three letters indicate the functionality and type of the variable. These letters are followed by the area abbreviation consisting of two to three letters with the following meanings: HFT circuit (HTF), kinematics unit (CI), translational motion (TRA), rotational motion (ROT) and motion control (MOT). The subsequent number ensures a clear identification of each single variable. The letter “W” shows that the variable processes an external wired signal. Input variables which are coming from an external signal and are transmitted via the OPC server are indicated by the letter O. The definition and assignment of variable names also called “tags” of the PLC in- and outputs is represented in the signal list suffixed in Appendix 14.12. The signal list was created by various authors. During the PLC configuration and programming process some inconsistences were noticed. Most discrepancies were corrected but a certain inconsistency remains.

9.2 Programing Language

Due to the environment the most of the PLC program is written in Ladder Diagram (LAD / LD). It is the preferred language of the Ciemat PSA instrumentation department. By using this language the program code can be modified easily by the on-site engineers later on. This is especially important for the program maintenance and further development. A disadvantage of LD is its rather unclear layout especially for people without experience in reading electric circuit diagrams and electric logic combination controls. Using functional blocks from the Functional Block Diagram (FBD) language a better clarity is achieved.
For implementation of technology hardware and some user specified functions the language Statement List (STL) is used. STL offers instructions which are not available in other languages. Furthermore it allows quicker code writing. STL corresponds to the Instruction List (IL) language defined in the IEC 61131-3 specification.

10 Implemented functions

In order to allow various motions of the test rig different functions were implemented. These functions are described in the SCADA outline. By the SCADA outline the control tasks are assigned to the responsible SCADA system elements. In the following an extract of the SCADA outline is given. This extract describes the operations of the kinematics unit and therefore the motion control.

10.1 Description of functions by an extract of the SCADA outline

In the present outline the divisions and assignments of main areas and tasks are represented in the following scheme:

Main Area [responsible subsystem]

Description and general information

Interface

Outputs and inputs <- [responsible subsystem]

Variables – tag

Description, information

Task Level 1 [responsible subsystem]

Description and general information

Interface

Outputs and inputs <- [responsible subsystem]

Variables – tag

Description, information

Task Level 2 [responsible subsystem]…

…

Task Level 3 [responsible subsystem]…

…

10.1.1 Extract of SCADA outline

Operate Kinematics Unit [PLC&LV]

This section treats the operation of the Kinematics unit and therefore the motion control.

Enable Kinematics Unit [PLC]

By calling the function “Enable Kinematics Unit [FC28]” the equipment related to the kinematics unit is activated. By these means of action, the mains of the hydraulic oil cooler pump, the servo controller and the VFD as well as the corresponding power enable ports are activated. It is called during the (re-)start of the PLC system.

```
Variables:
Mains Hyd. oil cooler pump – “EY-CI-10-W”
Mains servo controller (6SC1) - ”EY-CI-12-W”
Mains VFD (7FC1) - ”EY-CI-13-W”
Power stages enable – ”Enable-motion” [FC20]
```

Enable motion [PLC]

The function enables the power stages (ENPO) of the VFD (7FC1) and the servo controller (6SC1) to operate.
It is called within the “Enable Kinematics Unit” function but also on external request. This is necessary to restart motions after a critical incident.
Implemented in: motion-control [FC21], Network: ENPO – motion.

```
Variables:
ENOP servo controller (6SC1) - ”YY-CI-05-W”
ENPO VFD (7FC1) - ”YY-CI-07-W”
```

```
Interface
Input: <- [LV]
    Variables:
    Activate power stages - ”DB_motion-control”.”EK-MOT-01-O-enpo”
```

Manual Mode

The manual mode allows a manual control of the kinematics unit by the user. Therefore it provides various functions which are organized within the PLC Motion-control function [FC21]. The function Motion-control [FC21] coordinates the motion control and is called frequently by the organization block “Main” [OB1]. Within this block the status of the Boolean variables which can be set by LV via the OPC server, are queried. If a variable is set, the corresponding functions are called. Another task is to identify and process inconsistent external motions commands coming from LV. For this task the internal temporary variables “count_calls_rotation” and “count_calls_translation” count the respective function calls during one motion-control cycle, the value should not exceed 1 otherwise inconsistent instructions were given. Such an incident is indicated by the variables: "Y-TRA-01_inconsistent instructions" and "Y-ROT-01_inconsistent instructions". The organization of external requests and the testing of their consistence are treated within one function to achieve a clear arrangement.

Stop Motion [PLC]

This function provides the option to stop the motion via the user interface during the manual operation. When the function is called the pumps and valves will be deactivated. There also exists an additional, independent hardware emergency stop, activated by emergency stop switches. Furthermore it resets external motion requests.
Implemented by: motion-control [FC21], Network: Stop-motion.

Interface

Input: <- [LV]

Variables:

Stop motion –"DB_motion-control"."ZYK-MOT-01-O-stop-motion"

Manual Mode rotational Motion

General feedback from PLC to LV. The outputted values are stored in global variables and processed within various functions. They contain information which is of interest for various motion functions.

Interface

Output: [PLC] ->

Variables:

Actual angle – "ZQ-ROT-01-actual-angle"

Rotation stopped – critical -"ZY-ROT-09-stopped-critical"
Set when rotation was stopped by the PLC because of a critical incident

Virtual limit reached positive - "ZY-ROT-01-0-HL-reached" (Software)

Virtual limit reached negative - "ZY-ROT-02-O-LL-reached" (Software)

Limit switch reached positive – "ZS-CI-02-HL" (Hardware) blocks positive rotation [FC10] [PLC]

Limit switch reached negative – "ZS-CI-01-LL" (Hardware) blocks negative rotation [FC12] [PLC]

Rotate [PLC]

The drive rotates in either negative or positive direction until the end position is reached or the motion is stopped by the user.
Implemented by: motion-control [FC21], Networks: start positive rotation – external request, start negative rotation – external request, stop rotation – external request.

Interface

Input: <- [LV]

Variables:

Speed – "DB_A-Output".AO_Module_16.AO_CH2."SC-CI-03-W" (As % of motor speed)

Start positive direction - "DB_motion-control".Rotation."ZK-ROT-01-O-start-pos"

Start negative direction - "DB_motion-control".Rotation."ZK-ROT-02-O-start-neg"

Stop - "DB_motion-control".Rotation."ZYK-ROT-01-stop"

Rotate to Position X [PLC]

The drive rotates until it reaches the designated position X.
Implemented by: motion-control [F21], Network: rotate to position X.

Interface

Input <- [LV]

Angle X - "DB_motion-control".Rotation."ZK-ROT-03-O-sp-angle-X"

Speed – "DB_A-Output".AO_Module_16.AO_CH2."SC-HFT-03-W" (As % of motor speed)

Start - "DB_motion-control".Rotation."ZK-ROT-04-O-start-rotate-to-X"

Output: [PLC] ->

Position X reached – "ZY-ROT-04-position-reached"

Rotation Step [PLC]

The drive will do one step of 0.25 ° (defined in "DB_motion-control".Rotation."ZU-ROT-02-stepwidth"). Unlike to the other motion functions, the hydraulic valves continue in their position after the complete execution of a step. This is necessary to facilitate the execution of more steps in less time. If the desired step width is reached, has to be investigated during the commissioning of the motion control and the kinematics unit. Later, when the testing procedures are defined, this function can be modified and enhanced.
Implemented by: motion-control [F21], Network: Rotate-step

Interface

Input: <- [LV]

Do Step positive - "DB_motion-control".Rotation."ZK-ROT-05-O-step-pos"

Do Step negative - "DB_motion-control".Rotation."ZK-ROT-06-O-step-neg"

Output: [PLC] ->

Step executed – "ZY-ROT-05-step-executed"

Debug Mode Rotation [PLC]

The debug mode enables a single and independent cylinder movement. This function should be used only under the highest awareness. By moving one cylinder against the other the mechanical structure or the cylinders themselves might be damaged. Therefore it must be ensured that a mal-function or crash of either the LV- or OPC-system does not lead to an unstoppable cylinder movement. It was decided that the stop of the cylinder movement in case of a crash or mal-function will be task of the LV-system or the OPC server.

Implemented by: motion-control [F21], Network: Debug-rotation

Interface

Input: <- [LV]

Debug mode enable - "DB_motion-control".Rotation."ZK-ROT-07-O-debug-mode-enable"

Extend cylinder rot.west - "DB_motion-control".Rotation."Debug-mode-rotation"."ZK-DEB-01-O-exte-rot.west"

Retract cylinder rot.west - "DB_motion-control".Rotation."Debug-mode-rotation"."ZK-DEB-02-O-retr-rot.west"

Extend cylinder rot.east - "DB_motion-control".Rotation."Debug-mode-rotation"."ZK-DEB-03-O-exte-rot.east"

Retract cylinder rot.east - "DB_motion-control".Rotation."Debug-mode-rotation"."ZK-DEB-03-O-exte-rot.east"

Stop - "DB_motion-control".Rotation."ZYK-ROT-01-O-stop"

Manual Mode Translational Motion [PLC]

General feedback from PLC to LV. The outputted values are stored in global variables and processed within various functions. They contain information which might be changed as a result of the execution of various motion functions.

Interface

Output: [PLC] ->

Actual angle – "ZQ-TRA-01-actual-angle"

Virtual limit reached positive – "ZY-TRA01-HL-reached" (Software)

Virtual limit reached negative – "ZY-TRA-02-LL-reached" (Software)

Limit switch reached positive - "ZS-CI-05-HL" (Hardware) blocks positive translation [FC24]

Limit switch reached negative - "ZS-CI-04-LL" (Hardware) blocks negative translation [FC26]

Translational Motion [PLC]

When started, the translation drive moves in either negative or positive direction until the end position is reached or the motion is stopped by the user.
Implemented by: motion-control [FC21], Networks: "start positive translation - external request", "start negative translation - external request".

Interface

Input: <- [LV]

Speed - "DB_A-outputs".AO_Module_16.AO_CH1."SC-CI-02-W" (As % of motor speed)

Start positive direction - "DB_motion-control".Translation."ZK-TRA-02-O-start-pos"

Start negative direction - "DB_motion-control".Translation."ZK-TRA-03-O-start-neg"

Stop - "DB_motion-control".Translation."ZYK-TRA-01-O-stop"

Translational Motion to Position X

The translation drive moves linear until it reaches the entered position X.
Implemented by: motion-control [FC21], Network: Translational-motion-to-position

Interface

Input: <- [LV]

```
Angle - "DB_motion-control".Rotation."ZK-ROT-03-sp-angle-X"
Speed - "DB_A-outputs".AO_Module_16.AO_CH1."SC-CI-02-W"
As percentage of motor velocity
Start - "DB_motion-control".Translation."ZK-TRA-05-O-start-motion-to-X"

Output: [PLC] ->
Position reached - "ZY-ROT-04-position-reached"
```

Automatic Mode [LV]?, [PLC]?

The automatic mode has to be developed after the testing procedures were defined and a good understanding of the system was gained. It might be considered to design the automatic mode mainly in LV whereby use of the existing PLC functions can be made.

11 System dynamics

The precession of positioning is not only limited by the accuracy of the position measurement but also by the change of position during one program cycle and the overall dynamic of the system.
The overall dynamic of the system depends on various factors. Some of these factors such as the reaction time of the PLC and the servo controller can be estimated. Other factors like the influence of the mass inertia of the system or the inertia of the hydraulic control system are unknown. To do an estimation on the overall dynamics of the system, data of all contributing parts is needed but the data and the dynamic behavior of many system components is not available. So the overall dynamics will be inspected by experiments once the mechanical constructions of the test rig is finished and basic functions, to generate a motion, are implemented.

11.1 Inspection of cycle time in respect to motion control

As further discussed under 3.2 a real-time system is defined by its guaranteed maximum cycle time. Many motion control systems need a short cycle time and therefore require especially high performance CPUs. These short cycle times are amongst other things necessary to achieve an accurate positioning.
In the following is explained why the cycle time has an impact on the positioning process:
The drive moves continuously with a certain velocity and the resulting positioning data is processed within a given time. At the time the processing is performed and the corresponding commands are generated as an output by the PLC, the drive won´t be in the same position as it was when the position values were determined. In other words, the cycle time contributes to a delay between the occurrence of an event and the corresponding reactions taken due to the event. In case of driving the drive to a desired position (set point) the result is an overshoot. This means that the actual position will not be the desired position but a position beyond this set point.
In the present application it is important to know the absolute position of the rotational motion, in order to act correctly when the so-called critical angles are reached. These critical

angles require a corresponding valve actuation depending on the angle area in which the motion is executed. This process is described in detail in 6.3.2.
Due to the geometry of the drive pylon the change in cylinder length is rather low within the nearby area of these angles. These can also be seen in the diagrams displayed in Figure 29 and Figure 30 in chapter 6.3.2. The curves show a relative small slope around the critical angles. This circumstance allows a rather coarse motion control without damaging the drive pylon.

11.2 Introduction of a tolerance band

The above mentioned delay does not only have an influence on the accuracy of the absolute positioning but can also provoke oscillations. Due to the time needed to process the data, the drive will stop at a final position beyond the set point. If the system wants to compensate this overshoot, it will send the drive in the opposite direction. But here again an overshoot will occur. The result will be a continuous back and forth motion.
To prevent such a back and forth motion and therefore the oscillation of the system a tolerance band is introduced in the program. By the implementation of a tolerance band a certain deviation of the actual position value is allowed. If the actual position value is within the tolerance band no further motion will be executed.

11.3 System dynamics and rotational motion

The angle $\Delta\varphi$ (maximum change of the rotation angle φ within one program cycle of the reference system) contributes directly to the uncertainty of positioning and must be taken into account while defining the position tolerance band.
As a first approach a tolerance band of ± 0.1° was chosen for the rotation angle. This value was chosen in orientation on an existing reference system. The applicability of this value has to be investigated through an experimental approach.

11.3.1 Comparison with existing system

To gain an understanding on the influence of the program cycle time on the positioning, a comparison with a motion control of an existing PTC is executed in the following.
As described under 1.2.1 there are different sun tracking methods. If the sun is followed by an algorithm, it is important to be able to achieve a sufficient accurate positioning. This is required to keep the HCE within the focus and obtain a good efficiency. On the PSA various systems are operating in such a way, whereby the motion control is realized by micro controllers. To estimate the needed cycle time of the present CPU the test rig is compared with an existing system and values resulting from the PSA instrumentation department experience. These values aren´t documented but only provided verbally or reconstructed from program code of existing systems.

<table>
<tr><th colspan="2">Rotational motion</th></tr>
<tr><th>Reference
(existing system or values based on experience)</th><th>Test rig</th></tr>
<tr><td colspan="2">Angular velocity ω</td></tr>
<tr><td>$\omega_{ref} = 0.6\ °/s$</td><td>Angular velocity of rotational motion $\omega_{\varphi\, test\, rig}$:
$$\omega_{\varphi\, test\, rig} = 2 \cdot \frac{210°}{5 \cdot 60\ s} = 1.4\ °/s$$
The test rig is designed to drive twice through the whole angle range (210°) (one cycle) in 5 min. This leads to an angular velocity of 1.4° /s</td></tr>
<tr><td colspan="2">Cycle time T</td></tr>
<tr><td>$$T_{ref} = \frac{1\ s}{8} = 125\ ms$$
Eight positioning program cycles per second</td><td>$$T_{test\, rig} = \frac{\Delta\varphi_{ref}}{\omega_{\varphi\, test\, rig}} = \frac{0.075°}{1.4\ °/s} = 53.6\ ms$$
To achieve the same Δφ as in the reference system a cycle time of $T_{testrig} \leq 0.0536\ ms$ is needed.</td></tr>
<tr><td colspan="2">Maximum change of the rotation angle φ within one program cycle Δφ</td></tr>
<tr><td>Maximum change of the rotation angle φ within one program cycle of the reference system $\Delta\varphi_{ref}$:
$$\Delta\varphi_{ref} = T_{ref} \cdot \omega_{ref} = 125\ ms \cdot \frac{0.6°}{s} = 0.075°$$</td><td>Not yet know</td></tr>
<tr><td colspan="2">Resolution of rotation angle measurement R_φ</td></tr>
<tr><td>1 bit ≙ 0.036°
$R_{\varphi ref} = 0.036°$</td><td>$$R_\varphi = \frac{R_{digit} \cdot 360°}{c} = \frac{5\ \mu m \cdot 360°}{500\ mm} = 0.0036°$$</td></tr>
<tr><td colspan="2">Tolerance band</td></tr>
<tr><td>Tolerance: ± 0.1°</td><td>For a first approach chosen to be ± 0.1</td></tr>
<tr><td colspan="2">Tracking</td></tr>
<tr><td>Algorithm, each 3 s</td><td>none</td></tr>
</table>

The reference system moves with angular velocity of about ω_{ref} = 0.6 °/s, the position value is processed eight times per second. This leads to a maximum change of the rotation angle $\Delta\varphi$ within one program cycle of $\Delta\varphi_{ref}$= 0.075°. The test rig is designed to drive twice through whole angle range (210°) in 5 minutes. This leads to an angular velocity of 1.4 °/s
In order to achieve the same $\Delta\varphi$ with the test rig ($\Delta\varphi_{\text{test rig}} = \Delta\varphi_{\text{ref}}$), a cycle time of $T_{test\ rig} \leq 0.0536\ ms$ is needed.

11.4 System dynamics and translational motion

The test rig was designed to drive, in the translational axis, through a range of 45° within 15 seconds. This leads to an angular velocity $\omega_\theta = 3°/s$:

$$\omega_\theta = \frac{45°}{15\ s} = 3°/s$$

If a maximum cycle time of 53.6 ms, as derived in 11.3.1, is assumed an angular velocity of $\omega_\theta = 3°/s$ would lead to a maximum change of the translation angle θ within one program cycle $\Delta\theta = 0.16°$:

$$\Delta\theta = T_{assumed} \cdot \omega_\theta = 53.6\ ms \cdot \frac{3°}{s} = 0.16°$$

Under the consideration of $\Delta\theta$ for the positioning in the translation axis a tolerance band of ± 0.2° was chosen as a first approach. In the case that a higher precision is needed the tolerance band could be narrowed by slowing down the translational motion. This can be done by the VFD driving the hydraulic pump.

11.5 Actual cycle time and possible improvements

It is yet not known, if this cycle time will be achieved with the present hard- and software. Neither it´s known to which extend the cycle time influences the dynamic of the system and therefore the possibility to reach the desired step width of 0.25°.
To gain a better knowledge on the performance, the behavior and the impact of the individual components tests and investigations will be done after the mechanical constructions are finished.
In the PLC configurations, the maximum cycle time can be set. If this cycle time is exceeded the CPU will go into the STOP mode. This is a necessary measure to fulfill the specifications for a real-time system. The default value for the maximum cycle time is 150 ms, this value can be adjusted between 1 ms and 6 s. In case that the resulting cycle time is to high different measures can be taken:

a.) It may be possible to reduce the cycle time by a redesign of the program code, in such a manner that less computing performance is needed.
b.) The hardware could be replaced by hardware with better computing power.
c.) Since not all processes require the same cycle time the program could be written in such a way that the time critical motion control process is called with a higher frequency than the remaining code. This can be realized by a periodic timer interrupt.
d.) The motion control can be outsourced to a certain extend. So, the servo controller could regulate the step width. To realize such a control the behavior of the complete system must be well known since there is no direct feedback of the actual position or

step width to the servo controller. But if the relation of rotational motion in respect to motion of the servo motor is known, an open loop control within limits can be a thinkable solution.

12 Summary of motion control parameters and specifications

In Table 8 the most significant parameters of the test rig motion are displayed. In the column “as planned” the values used during the planning process are shown. Some of these values were not actively considered during the planning process in this case the values resulting straight forward from the design are displayed. During the construction process deviations from the planned parameters to the actual parameters as they will be achieved by the test rig were noticed. These values are represented in column “as build”. To be able to relate these parameters, typical values of real world applications are shown in the column “Compare to”.

Table 8: Summary of motion control parameters and specifications

Variable	Unit	Test rig		Compare to	Source / comment
		as planned	as built		
Rotation angle φ					
Tolerance of measurement system		$\pm(0.0108° + 0.004\,\%_{m.v.})$		± 0.1°	m.v. = of the measured value See App. 14.9.1
Full range	°	[-120,90]		[-124,91]	SF, see App. 14.6
Day cycle range	°	[-120,90]		[-124,91]	SF, see App14.6.
Stow position	°	-120		-124	SF, see App. 14.6
End position	°	90		91	SF, see App. 14.6
Rotational motion					
Max. speed	°/s	1.4		0.6	See 11.3.1
Step interval	s			20-40; max 3	See 11.3.1; [8]
Step size	°	≤ 0.25			See 3
Positioning precision	°	± 0.1[2]		± 0.1	First approach; See 11.2
Translation angle θ					
Tolerance of measurement system	°	± 1	± 0.011	not measured	See App.14.7.2
Full range	°	[0,45]	[-19,28][1]		calculations based on geometry as planned
Day cycle range	°		[-5.65,17][1]	[-3,17]	SF, calc. based on App. 14.6
Translational motion					
Cylinder speed	m/s	0.03			Cylinder stroke (requirement sheet) See 3
Angular velocity	°/s	3			45° in 15 s See 6.3.1
Positioning precision	°	± 0.2[2]		none	First approach; See 11.411.2

[1] Range possibly smaller due to mechanical obstacles.
[2] Tolerance of measurement system excluded.

13 Summary and outlook

The aim of this bachelor thesis was to develop a motion control system for an already designed test rig which analyzed rotation and expansion performing assemblies in parabolic trough collector power plant applications. To gain an understanding of the general context, a brief summary of PTC and especially REPA technologies was first displayed. This was continued by presenting the motivation for an REPA test rig, and an overview of its design was given. It was explained how the motion control system will be embedded in the SCADA system. Hence the SCADA system and its components were discussed. Since a real-time system is needed, in order to prevent damaging the test rig, a PLC (SIMATIC S7-300 manufacturer Siemens) was selected as the base for the motion control system.

After defining the test rig motions in more detail and by overtaking information from previous investigations, the requirements of the REPA test rig motions were clarified and presented subsequently. Thus, it was displayed how the translational motion will be implemented with the help of two hydraulic cylinders, whereby the hydraulic oil pressure will be generated by a pump driven by a VFD. The direction and the start as well as the stop of the motion will be controlled by the actuation of hydraulic valves. An absolute rotary encoder was elected to measure the translation angle. Although the rotational motion follows the same principals, it will require the two cylinders moving separately. By a geometrical calculation the need for two switching points (CA2 and CA3), in order to generate a rotational motion was found. To achieve the requirement of steps ≤ 0.25° in the rotational axis, the corresponding hydraulic pump will be driven by a servo motor and it was decided to measure the rotation angle by a magnetic scale sensor.

After the framework was built, functions enabling motions in the translation- and rotation axis, as well as the positioning at a set point, were programmed. Moreover a function to execute 0.25° steps in the rotation axis was provided. Hereby, the motion is controlled directly via the servomotor, while the hydraulic valves remain most of the time in their position. This is a key point to facilitate a fast execution of these small steps.

During the discussion of the system dynamics it was shown how the PLC CPU cycle time affects the motion control. Furthermore it was described why it influences the positioning. If the cycle time will be small enough, is not yet know. Hence, possible improvements and alternative solutions are presented and an overview of the motion control parameters and specifications is given above (see, 12).

Within the scope of the bachelor thesis, the design of the motion control system was developed and its components were specified. However, only tests on single elements but not on the entire system were performed. The construction of the REPA test rig was not finished when this thesis was presented. Experience showed that the mechanical construction and the commissioning process are accompanied by continuous changes, improvements as well as adaptions. Since the presented test rig is a prototype, many factors and its behavior can only be predicted but remain unproven or uncertain until tests are performed. Thus an extensive testing and commissioning process including further corrections and improvements will be carried out subsequent to this thesis. According to the current time table the test rig will be operating and ready to execute measurement campaigns as of 2017.

List of Figures

List of Tables

References

[1] R. Pachauri and L. Meyer, "Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," IPCC, Geneva, Switzerland, 2014.

[2] T. F., S. C., O. M., P. T. and Hoyer-Klick, "Global Potential of Concentrating Solar Power," 15th SolarPACES Symposium, Berlin, Germany, 2009.

[3] "solargis.com," [Online]. Available: http://solargis.com/assets/graphic/free-map/DNI/Solargis-World-DNI-solar-resource-map-en.png. [Accessed 07 November 2016].

[4] A. Fernández-García, M. Cantos-Soto, M. Röger, W. C., H. C. and M.-A. L., "Durability of solar reflector materials for secondary concentrators used in CSP systems," Elsevier Solar Energy Materials & Solar Cells, 2014.

[5] "heliotrough.com," Flagsol, [Online]. Available: http://www.heliotrough.com/history.html#url. [Accessed 08 November 2016].

[6] energie.pr-gateway.de, "Kleiner Kollektor – große Wirkung," [Online]. Available: http://energie.pr-gateway.de/smirro-kleiner-kollektor-grose-wirkung/. [Accessed 8 December 2016].

[7] B. Informationsdienst, "Parabolrinnen-Kollektortechnik," [Online]. Available: http://www.bine.info/publikationen/themeninfos/publikation/solarthermische-kraftwerke-2/parabolrinnen-kollektortechnik/. [Accessed 8 December 2016].

[8] A. Plumpe, "Design of a Test Rig and its Testing Methods for Rotation and Expansion Performing Assemblies in Parabolic Trough Collector Power Plants," RWTH Aachen University, Aachen, 2016.

[9] AFP, "(tagesschau.de)," [Online]. Available: https://www.tagesschau.de/multimedia/bilder/noor-solarpark-101.html. [Accessed 09 November 2016].

[10] "reneweconomy.com," 05 02 2016. [Online]. Available: http://reneweconomy.com.au/first-160mw-of-huge-noor-solar-thermal-plant-connected-to-moroccan-grid-18132/. [Accessed 09 November 2016].

[11] "solarmillennium," [Online]. Available: http://www.solarmillennium.de/deutsch/archiv/technologie/referenzen-und-projekte/andasol-spanien/andasol.html. [Accessed 08 November 2016].

[12] "swm," Stadtwerke München, [Online]. Available: https://www.swm.de/english/press/photos/renewable-energies.html. [Accessed 08 November 2016].

[13] C. Hilgert, C. Happich, T. Effertz and N. Janotte, "REPA Teststand," DLR Institut für Solarforschung, 2015.

[14] "Plataforma Solar de Almería," [Online]. Available: psa.es. [Accessed 02 November 2016].

[15] NI, "labview realtime module," [Online]. Available: http://www.ni.com/labview/realtime/#.

[Accessed 27 November 2016].

[16] M. Seitz, Speicherprogrammierbare Steuerungen für die Fabrik- und Prozessautomation, München: HANSER, 2012, pp. ISBN 978-3-446-44273-3.

[17] R. van Mark, Flexible Motherboard-Generation für Mehrkernprozessoren, Berlin: VDE Verlag, 2010.

[18] J. Payne, "PLC vs. PAC," 2013. [Online]. Available: http://www.controleng.com/single-article/plc-vs-pac/44448cf771be09bff7115c621633bd94.html. [Accessed 10 December 2016].

[19] NI, "Programmable Automation Controllers (PACs)," National Instruments, [Online]. Available: http://www.ni.com/pac/. [Accessed 20 December 2016].

[20] Siemens, "SIMATIC S7-300," [Online]. Available: http://w3.siemens.com/mcms/programmable-logic-controller/en/advanced-controller/s7-300/pages/default.aspx. [Accessed 16 December 2016].

[21] leveldevelopments, "solar-trackers," [Online]. Available: https://www.leveldevelopments.com/solar-trackers/parabolic-trough-concentrating-solar-power-csp/. [Accessed 05 December 2016].

[22] solarpowerworldonline, "positioning-parabolic-troughs," [Online]. Available: http://www.solarpowerworldonline.com/2011/07/positioning-parabolic-troughs/. [Accessed 05 December 2016].

[23] "parabolic-trough-systems," posital, [Online]. Available: https://www.posital.com/en/industries/renewable-energy/parabolic-trough-systems/parabol_1.php. [Accessed 05 December 2016].

[24] posital, "Position Sensors for Solar Parabolic Trough Systems," [Online]. Available: https://www.posital.com/en/industries/renewable-energy/parabolic-trough-systems/parabol_1.php. [Accessed 5 December 2016].

[25] "flagsol.com," [Online]. Available: www.flagsol.com. [Accessed 08 November 2016].

14 Appendix

14.1 Photos of REPA test rig

14.1.1 Photo of kinematics unit showing REPA

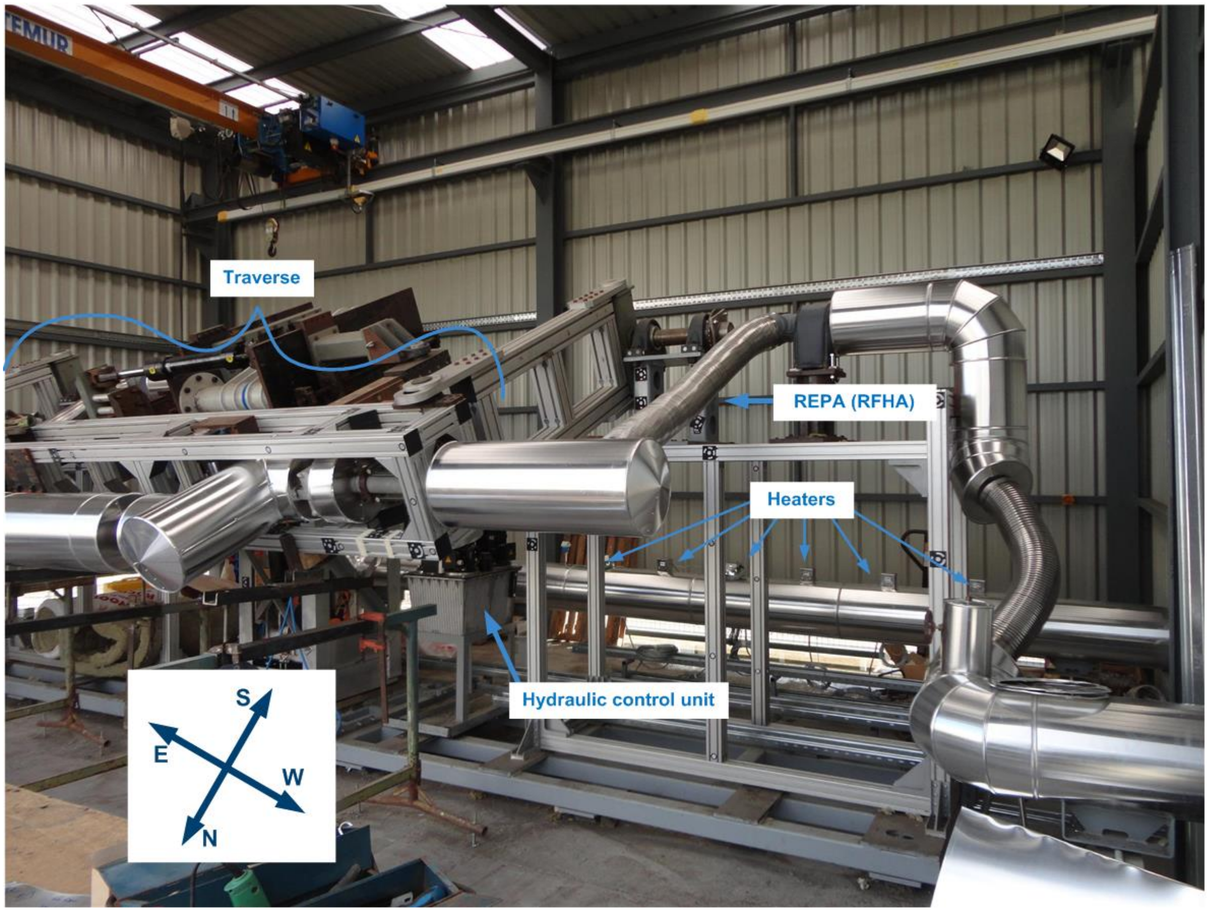
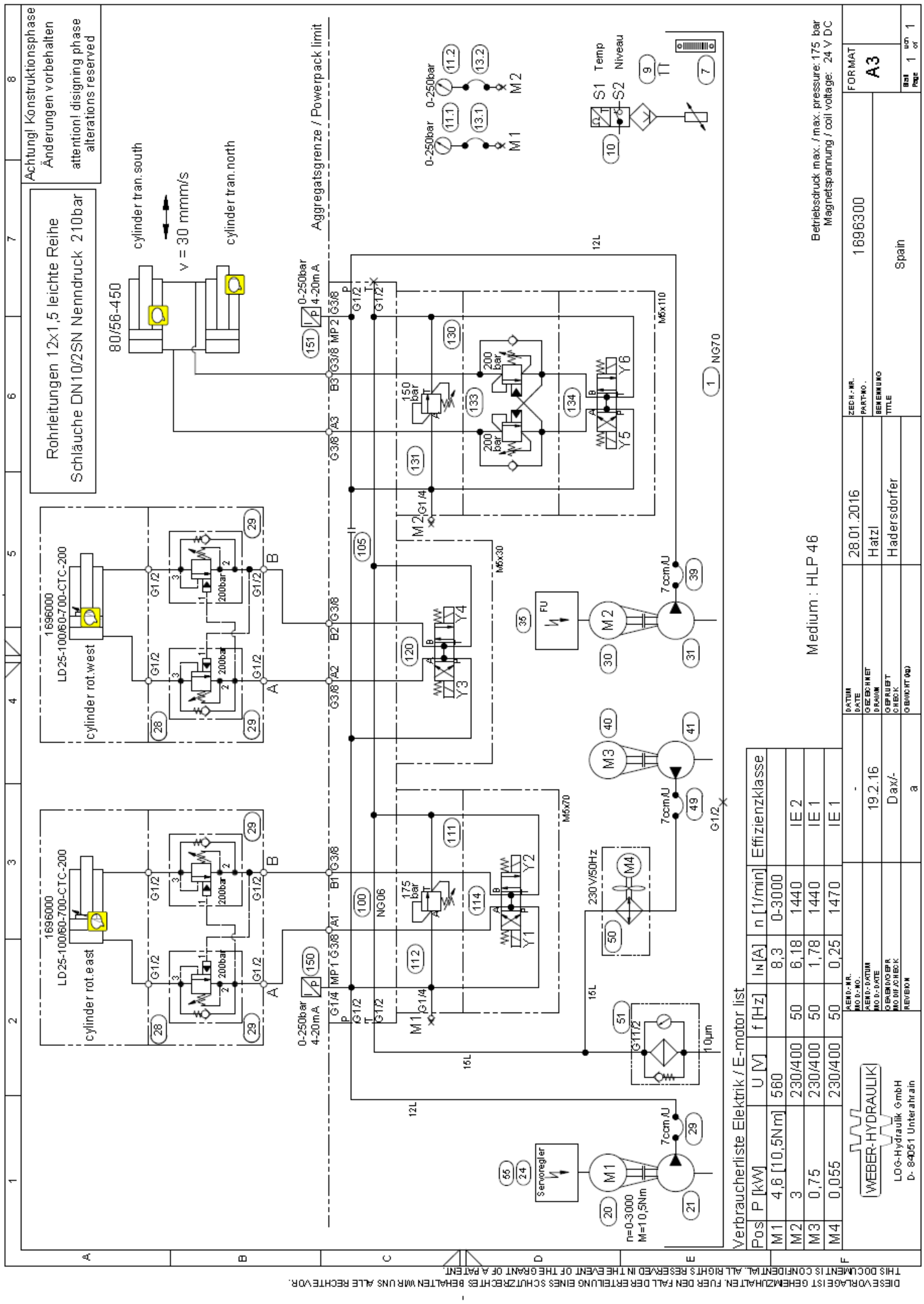


Photo of REPA test rig showing Kinematics unit

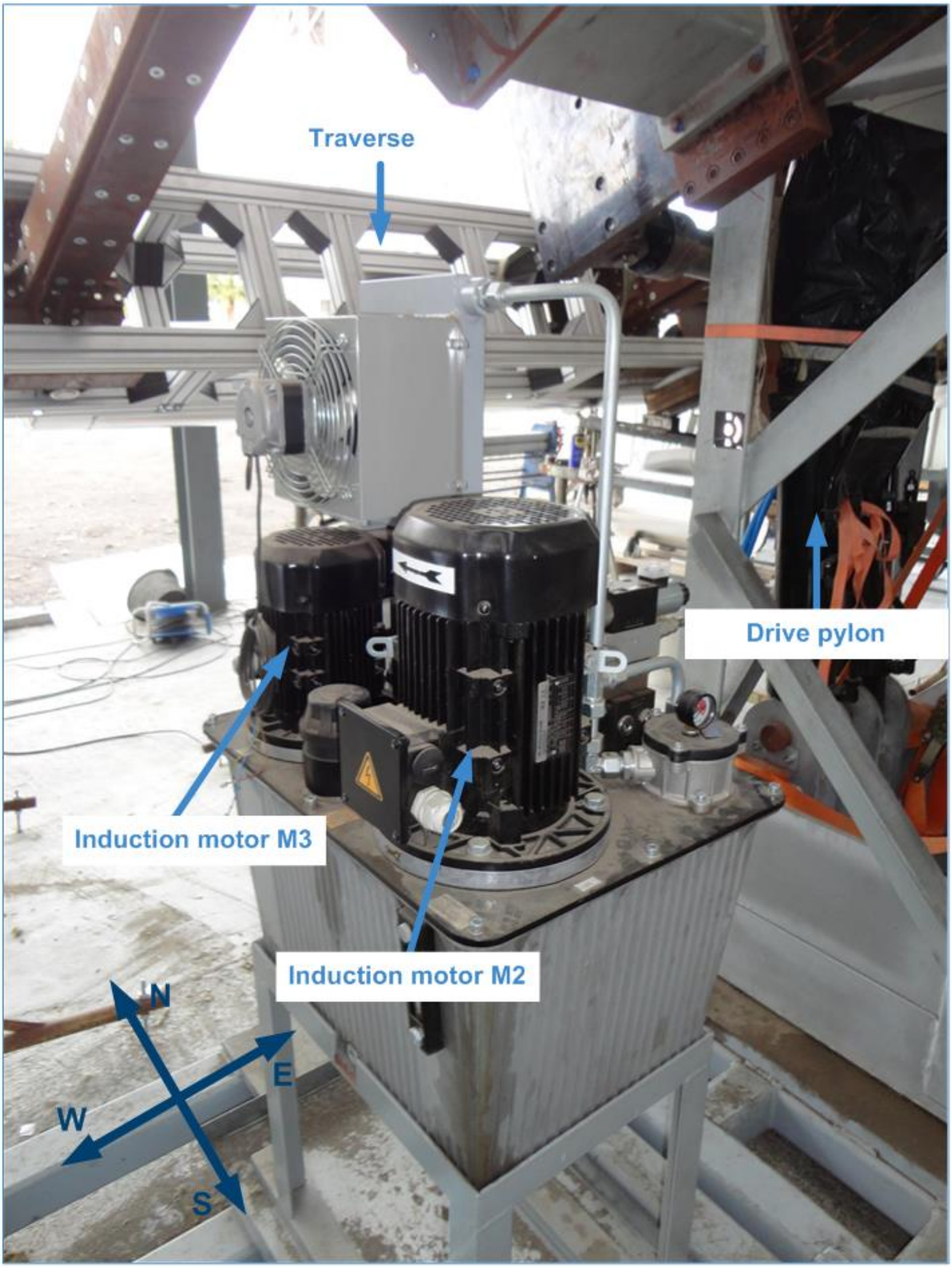
14.1.2 Photo of kinematics unit

14.1.3 Photo of HTF circuit

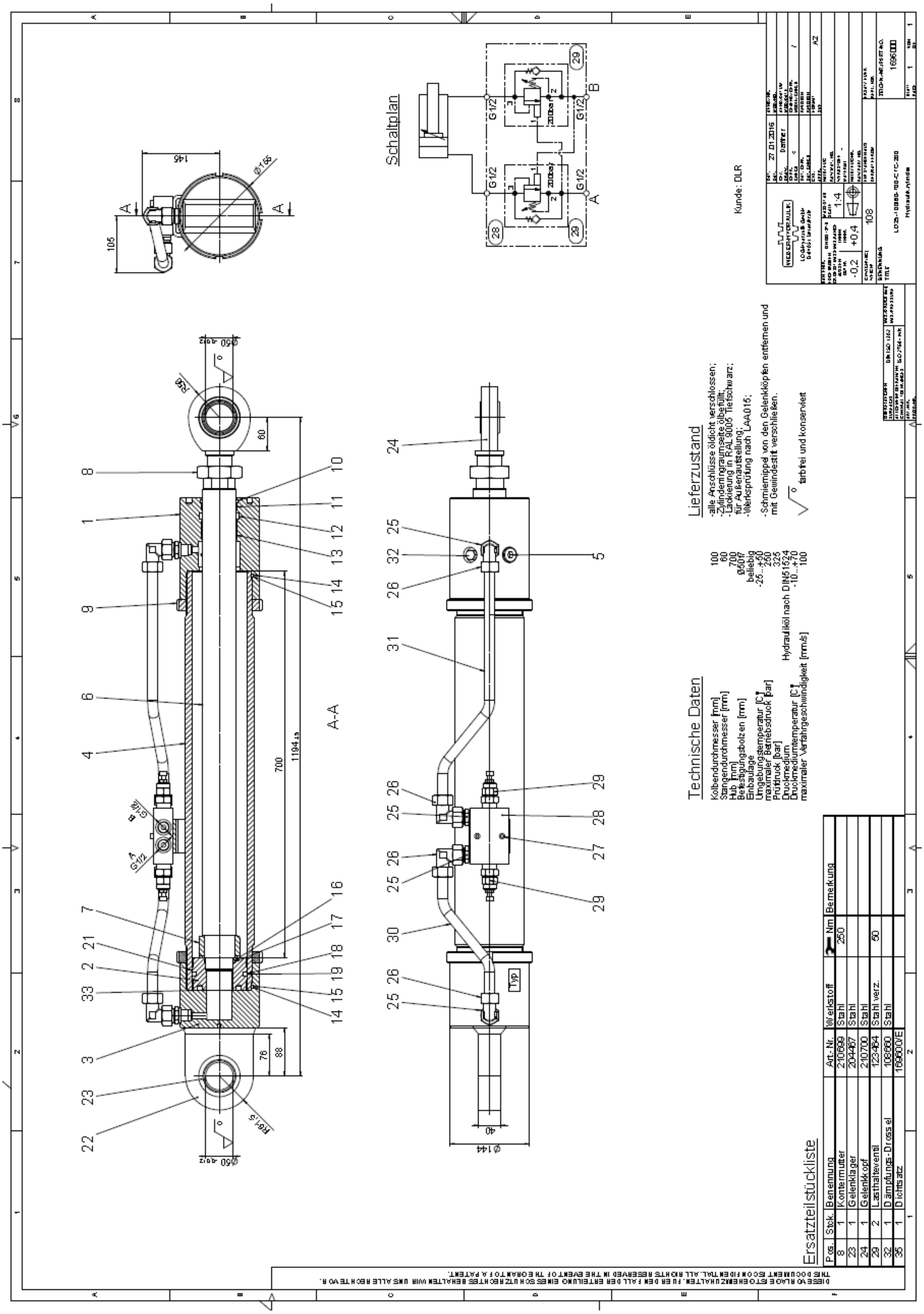
14.2 Hydraulic unit circuit diagram



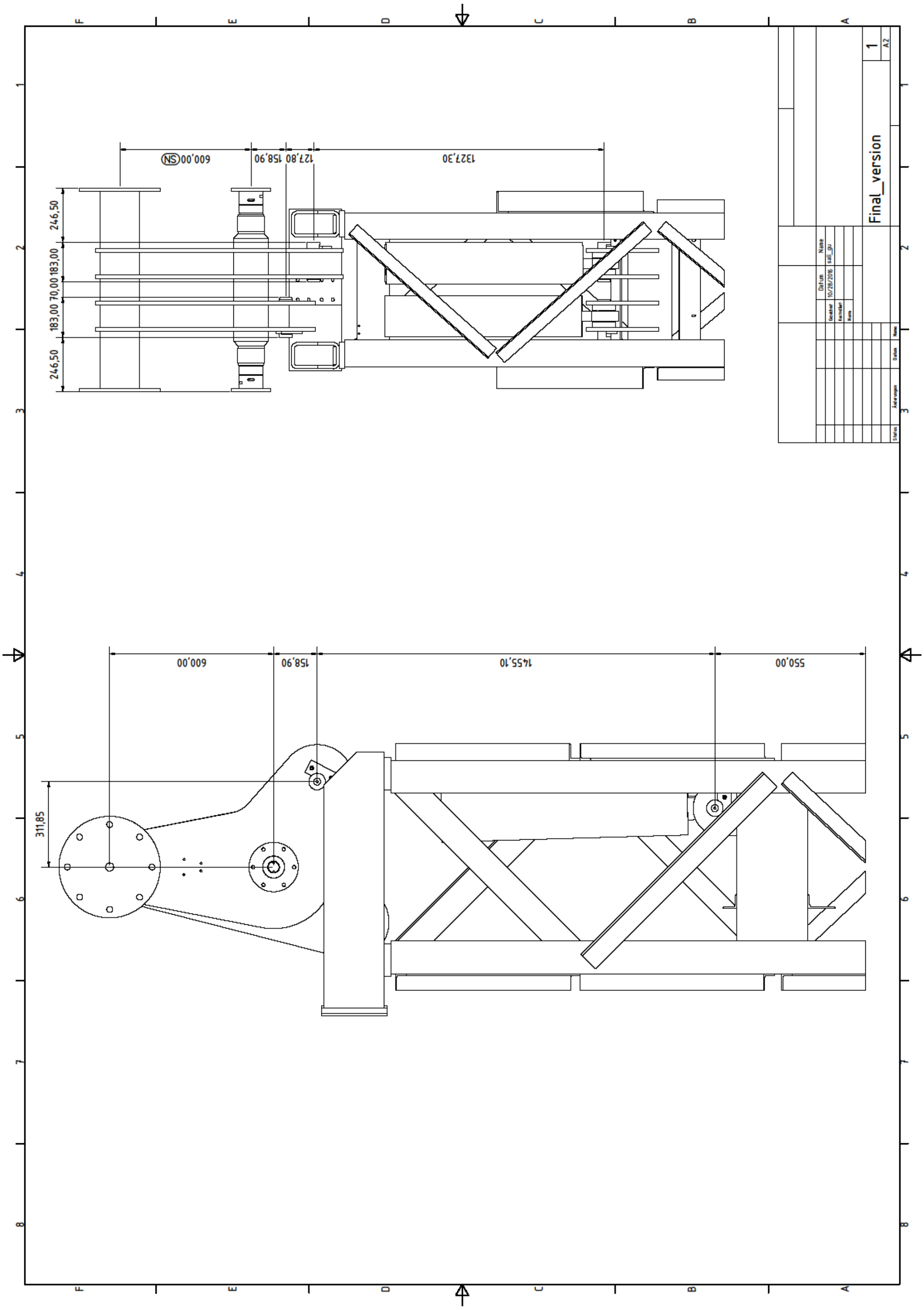
14.3 Photo of hydraulic control unit



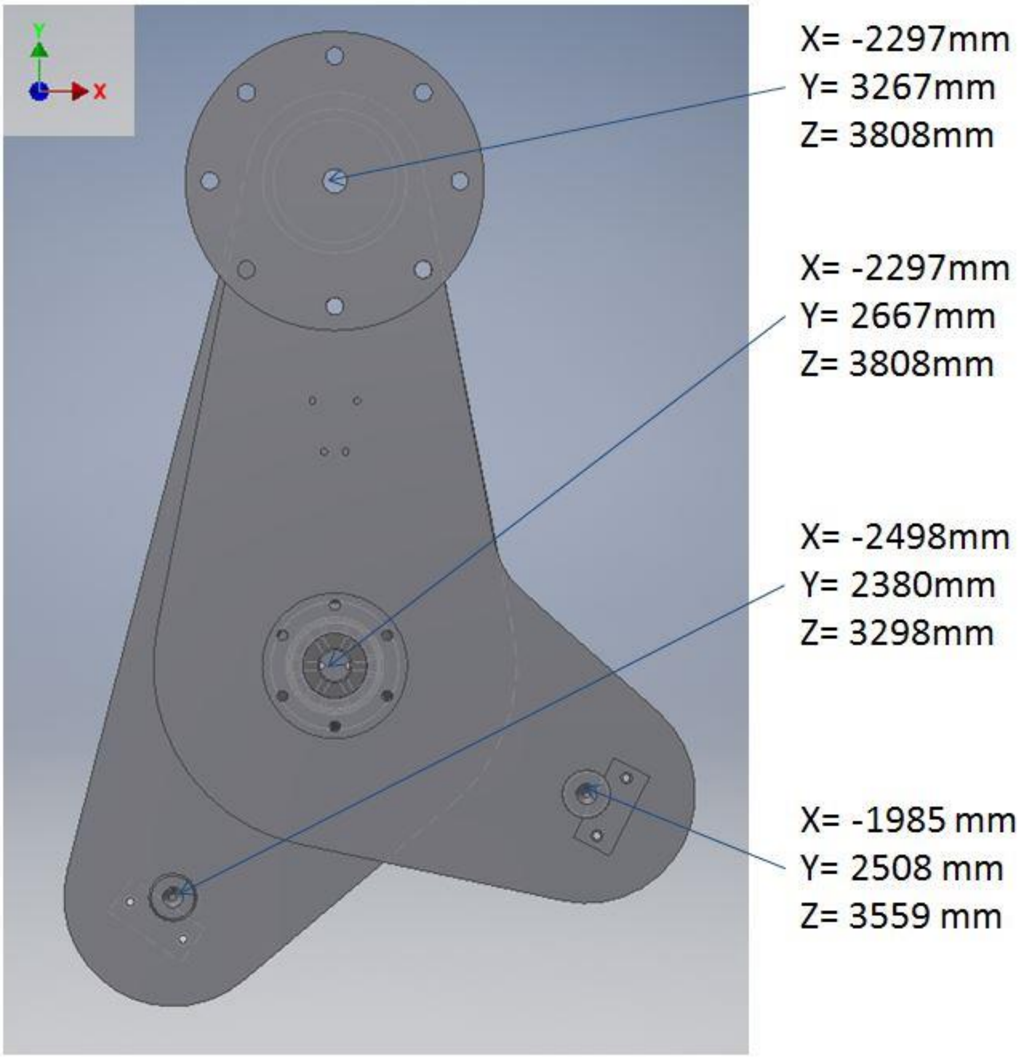
14.4 Technical drawing cylinder rotation



14.5 Drive pylon



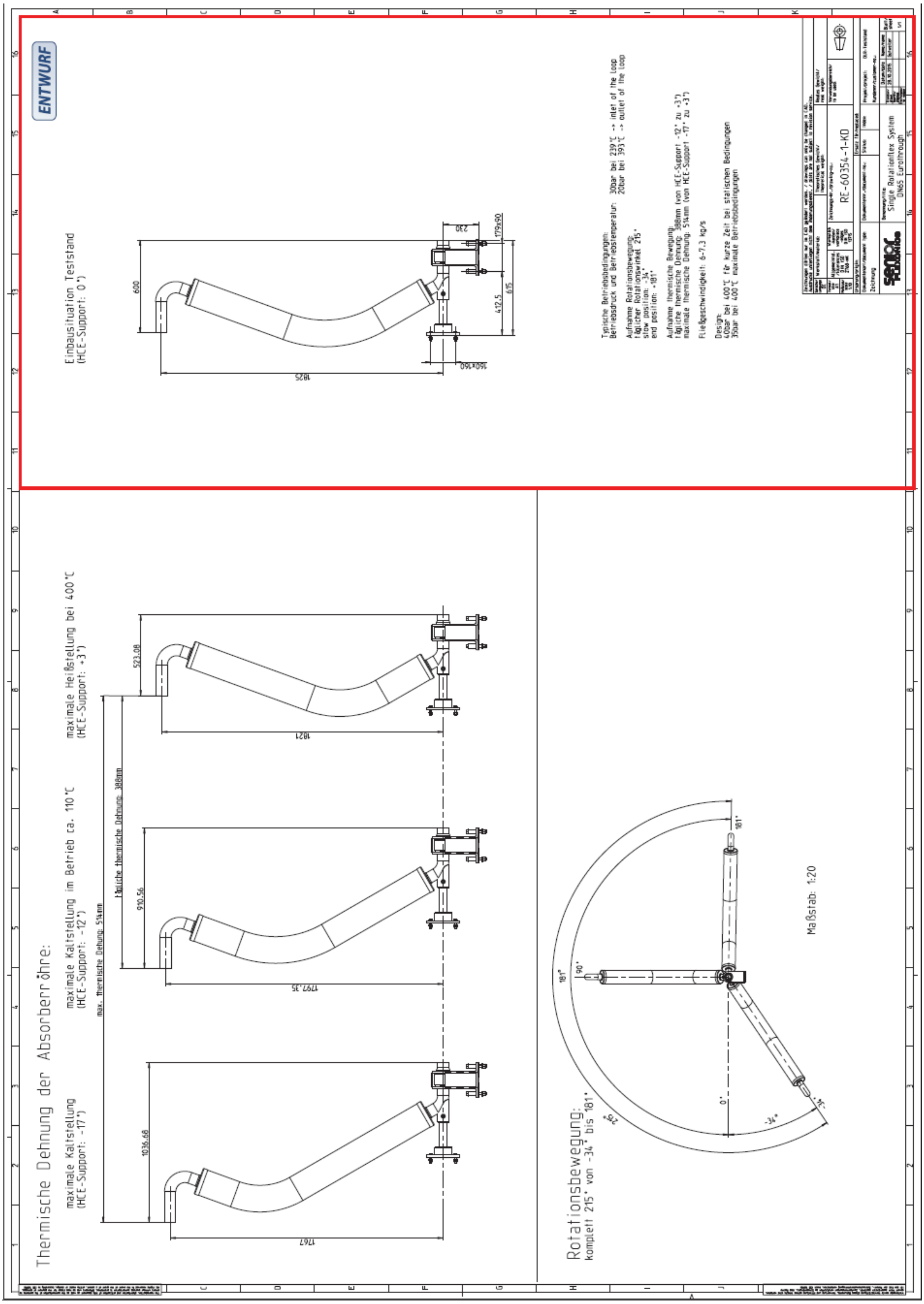
14.5.1 Drive pylon lever



14.5.2 Photo of drive pylon (lower part)

14.5.3 Photo of translation cylinder

14.6 Dimensions of RFHA, manufacturer Senior Flexonics (SF)



14.7 Absolute rotary encoder

14.7.1 Datasheet absolute rotary encoder

INDUcoder®

. . . The Right Position

ABSOlut enCODER EAM 58 / EAMS 58 Profibus

Optischer Absolut-Winkelcodierer,
Single-turn und Multi-turn mit hoher Auflösung

Codeurs optiques absolues haute résolution
Mono-tour et multi-tour
Standard de l'industrie, taille 58

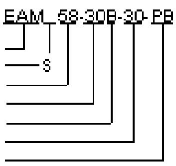
Optical absolute multi-turn shaft encoder
of high resolution Industrial standard package size

Auflösung	*Résolution*	Resolution
≤ 65536 Schritte/360° = 16 bit	*≤ 65536 points/tour = 16 bit*	≤ 65536 steps/turn = 16 bit

Meßbereich	*Gamme de mesure*	Measuring range
Single-turn 1 Umdrehung	*Mono-tour* *1 tour*	Single-turn 1 turn
Multi-turn ≤ 16384 Umdrehungen = 14 bit	*Multi-tour* *≤ 16384 tours = 14 bit*	Multi-turn ≤ 16384 turns = 14 bit

Aufbau/Vorteile	*Caractèristiques*	Features/Advantages
• Solider mechanischer Aufbau	• *Codeur robuste*	• Solid mechanical construction
• Schutzart IP 65, IP 66	• *Protection de IP 65, IP 66*	• Protection to IP 65, IP 66
• SMD-Elektronik	• *Èlectronique incorporée SMD*	• SMDtechnology
• Elektronische Justage	• *Réglage electronique*	• Electronic preset
• Programmierbar	• *Programmable*	• Programmable
• Profibus DP	• *Profibus DP*	• Profibus DP

Bestellschlüssel	*Tableau des modèles*	Ordering code
Winkelcodierer Type	*Codeur absolu*	Absolute Shaft Encoder Type
Servo-/Klemmflansch	*Face avant*	Flange type
Gerätedurchmesser	*Diamètre de l'appareil*	Package diameter
Anzahl der Bits	*Nb. de bit*	No. of bits
Ausgabe-Code Binär	*Code Binaire nat.*	Code Binary nat.
Speisespannung	*Tension d'alimentation*	Power supply voltage
Profibus	*Profibus*	Profibus



Auswahltabelle	*Tableau de sélection*	Selecting table	
Anzahl der Bits	*Nb. de bit*	No. of bits	12 = 12 bits x 1 turn 13 = 13 bits x 1 turn 16 = 16 bits x 1 turn 24 = 12 bits x 4096 turns 25 = 13 bits x 4096 turns 28 = 16 bits x 4096 turns 26 = 12 bits x 16384 turns 27 = 13 bits x 16384 turns 30 = 16 bits x 16384 turns
Speisespannung	*Tension d'alimentation*	Power supply voltage	30 = 10..30 VDC
Ausgangstreiber	*Amplificateur de sortie*	Output driver	PB = Profibus

AB58-311
Änderungen vorbehalten / *Sous réserve de changements* / Subject to change

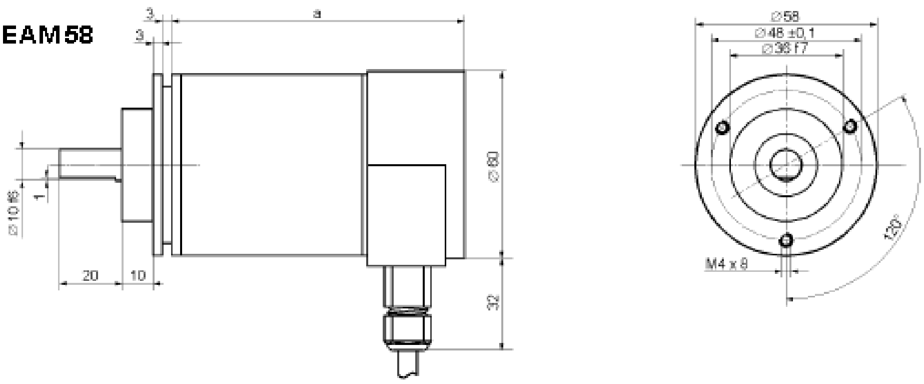
INDUcoder Messtechnik GmbH, Postfach 18 03 49, 47173 Duisburg - Germany, Tel. 0203/57047-0, Fax 0203/57047-20

hochschule mannheim

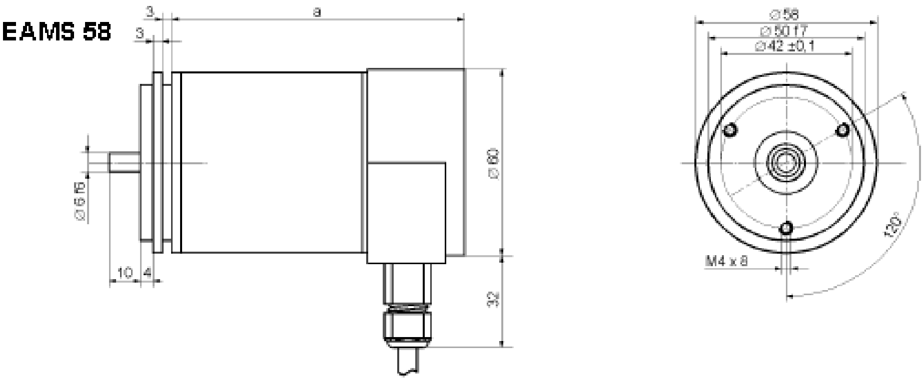
Technische Daten	*Caractéristiques techniques*	Technical Data	
Mechanische Werte	*Caractéristiques mécaniques*	Mechanical data	
Drehzahl	*Vitesse de rotation*	Rotational speed	≤ 12000 min^{-1} (Single-turn) ≤ 6000 min^{-1} (Multi-turn)
Drehmoment	*Couple*	Torque	≤ 3 Ncm
Trägheitsmoment	*Moment d'inertie*	Moment of inertia	≤ 30 g cm²
Wellenbelastung	*Capacité de charge de l'axe*	Shaft loading	40 N axial, 110 N radial
Lebensdauer der Kugellager	*Durée de service des roulements à billes*	Operational life of ball bearings	> 2 x 10^5 h (1000 min^{-1}, EAMS 58) > 1 x 10^5 h (1000 min^{-1}, EAM 58)
Gewicht	*Poids*	Weight	≤ 0,6 kg
Umgebungsbedingungen	*Conditions ambiantes*	Environmental conditions	
Vibration	*Vibrations*	Vibration	100 ms^{-2} (10 ... 1000 Hz)
Beschleunigung	*Chocs*	Shock	300 ms^{-2} (11 ms)
Arbeitstemperatur	*Température de travail*	Operating temperature	-40 ... +85 °C
Lagertemperatur	*Température de stockage*	Storage temperature	-40 ... +85 °C
Luftfeuchtigkeit	*Humidité de l'air*	Atmospheric humidity	< 98 % r.h.
Schutzart	*Protection*	Protection	IP 65 (EN 60529) IP 66 optional
Elektrische Werte	*Caractéristiques électriques*	Electrical data	
Optisch, berührungslos	*Optique, sans contact*	Optical, without contact	
Sender, Infrarot	*Émetteur, infrarouge*	Transmitter, infrared	LED
Empfänger	*Récepteur*	Receiver	Photo-Array
Abtastfrequenz LSB	*Fréquence de balayage LSB*	Scanning frequency LSB	800 kHz
Messgenauigkeit	*Exactitude de mesure*	Measurement accuracy	± ½ LSB (12 bit) ± 1 LSB (13 bit) ± 2 LSB (16 bit)
Speisespannung	*Tension d'alimentation*	Supply voltage	Vcc = 10...30 VDC
Stromaufnahme	*Consommation de courant*	Power consumption	≤ 100 mA (Vcc = 24 V)
Elektrische Anschlüsse	*Connections électriques*	Electrical connections	
Profibus	*Profibus*	Profibus	
Schnittstelle	*Interface*	Interface	RS485 with optocoupler
Taktfrequenz	*Fréquence de balayage*	Frequency	max. 12 MBaud

Massbild | ***Encombrement*** | **Outline drawing** | mm

EAM58



EAMS 58



a = 76 mm for Single-turn, 86 mm for Multi-turn

14.7.2 Absolute rotary encoder measurement tolerance

Manufacturer: INDUcoder
Type: EAM58PB

The absolute rotary encoder is used to measure the translation angle *theta* (θ).

Resolution rotary encoder: R_θ

$$R_\theta = \frac{360°}{2^{16\,Bit}} = 0.00549\,...°$$

Tolerance of the rotary encoder: u_θ

$u_\theta \triangleq \pm 2$ LSB (from Datasheet, see 14.7.1)
$u_\theta = \pm 2 \cdot R_\theta$
$u_\theta = \pm 0.011°$

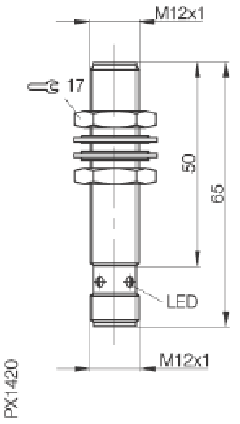
14.8 Inductive limit switch

14.8.1 Inductive limit switch datasheet

BES M12MI-POC40B-S04G
BES005N

PNP
NC
flush mountable

BALLUFF
sensors worldwide



Electrical data:

Utilization category	DC 13
Hysteresis max (H)	15 %
Off-state current max (Ir)	20 µA
Ripple max. of Ue	= 15 %
Voltage drop max static	2,5 V
Supply voltage max (Ub)	30 V
Connection	Connector S4 (M12)
Time delay before availability	30 ms
No-load supply current damped	= 15 mA
Switching output	PNP
Supply voltage min. (Ub)	12 V
Load current capacity (Ie)	200 mA
Rated operational voltage (Ue)	24 DC V
Electrical type	DC
No-load supply current undamped	15 mA
Switching element function	NC
Operating frequency (f)	300 Hz

Mechanical data:

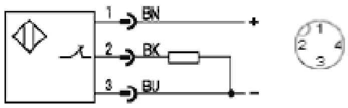
Tightening torque	15 Nm
Mounting	flush mountable
Degree of polution	3
Sensing face material	LCP
Rated operating distance (sn)	4 mm
Repeat accuracy max. (R)	5 %
Diameter	M12x1 mm
Assured operating distance	0...3,2 mm
Housing material	CuZn, nickel plated
Number of Wires	3-wire
Ambient temperature max	+70 °C
Ambient temperature min	-25 °C

General data:

Short circuit protected	yes
Protected against polarity reversal	yes
Degree of protection IP	IP68 per BWN Pr 20
Insulation class	2
Brand	GlobalProx
Approval	CE,c_ul_us
Output indication	yes

Wiring:

Pinout:
Pinout



www.balluff.com
Balluff Europe: +49 7158 173 -0
Balluff USA: 1-800-543-83 90
Balluff Asia: +86 21-50 64 41 31

Online Productinformation
2010-02-11

14.9 Magnetic scale position sensor

14.9.1 Magnetic scale position sensor measurement system tolerance

Circumference: *c* = 500 mm

Resolution of PMIS3 POSIMAG (with ext. times 4 counting mode) R_{digit} :

$R_{digit} = 5\ \mu m \quad ; \quad 1\ digit \triangleq 5\ \mu m$

Resolution in of rotation angle R_{φ} :

$$R_{\varphi} = \frac{R_{digit} \cdot 360°}{c} = \frac{5\ \mu m \cdot 360°}{500\ mm} = 0.0036°$$

Tolerance based on linearity sensor with mag. scale PMIB3 u_{lin} :

$u_{lin} \triangleq \pm 15\ \mu m\ \pm\ 40\ \mu m/m$ (see 14.9.2)

$$u_{lin} = \frac{15\ \mu m \pm 40\ \mu m/m}{R_{digit}} \cdot R_{\varphi} = \pm 0.0108°\ \pm 0.004\ \%_{\text{of the measured value}}$$

Tolerance based on repeat precision of sensor with mag. scale PMIB3 u_p :
$u_p \triangleq \pm 1\ digit$ (see 14.9.2)
$u_p = \pm 1\ digit \cdot \frac{0.0036°}{digit} = \pm 0.0036°$

Worst case estimation of rotation angle measurement system tolerance u_{φ} :

$$u_{\varphi} = u_{lin} + u_p$$
$$u_{\varphi} = \pm (0.0108° + 0.004\ \%_{\text{of the measured value}} + 0.0036°)$$

$$u_{\varphi} = \pm (0.014° + 0.004\ \%_{\text{of the measured value}})$$

14.9.2 Magnetic scale position sensor datasheet

Selected pages of the PMIS3 POSIMAG Magnetic Scale Position Sensor

PMIS3 POSIMAG®
Magnetic Scale Position Sensor

Very compact sensor for industrial applications
Sensor head PMIS3

- **Non-contact, no wear**
- **High velocity**
- **Robust shielded metal enclosure**
- **Protection class IP67**
- **Incremental encoder output A/B/Z**
- **Signal processing as usual with encoders**
- **Reference pulse and end position signal**
- **Indicator for velocity/position errors**

A POSIMAG measuring system consists of the sensor head PMIS3 and the magnetic scale PMIB3 with the same magnetic period.

Specifications

Output	Incremental encoder output A/B with differential push-pull output, TTL/RS422 or HTL compatible							
Excitation voltage	10 ... 30 VDC or 5 VDC ±5 %							
Excitation current	50 mA to 300 mA, depending on pulse frequency, cable length and load							
Magnetic period of the sensor	2 mm				5 mm			
Guided spacing between sensor and mag. scale (x_t)	0.1 ... 0.8 mm				0.1 ... 2 mm			
Side tracking tolerance of the sensor	±1 mm				±1 mm			
Linearity (sensor with mag. scale PMIB3)	15 µm ± 40 µm/m				30 µm ± 40 µm/m			
Repeatability	± 1 digit				± 1 digit			
Resolution with ext. times 4 counting mode [µm]	5	10	20	50	10	25	50	125
Max. velocity with fp=50 kHz [m/s] (20 kHz: x 0.4; 10 kHz: x 0.2)	0.8	1.6	3.2	8	1.6	4	8	20

Order code PMIS3

PMIS3 – □ – □ – □ KHZ – □ – □ – □ M – □

- Model name
- Magnetic period
  - 20 = 2 mm / 50 = 5 mm
- Resolution (in µm) with times 4 counting mode
  - Mag. period 2 mm: 5 / 10 / 20 / 50
  - Mag. period 5 mm: 10 / 25 / 50 / 125
- Max. pulse frequency (in kHz, standard 50 kHz)
  - 50 / 20 / 10
- Output
  - HTL = HTL output with excitation 24 VDC, output 24 V
  - TTL = TTL output with excitation 5 VDC, output TTL/RS422
  - TTL24V = TTL output with excitation 24 VDC, output TTL/10 mA
- Reference pulse/end position signal/status signal
  - Z0 = A/B w/o reference pulse / Z1 = A/B with reference pulse Z
  - Z2 = A/B with end position signal / *Z3 = A/B with reference pulse and status signal (Option Z3 only for non-diferential output, single ended)
- Cable length (in m, standard 2 m)
- Connection
  - S = Cable output, open end
  - P / P15 = SUB-D connector at the cable end: P = 9 pins; P15 = 15 pins

Order example: PMIS3 - 50 - 25 - 50KHZ - HTL - Z1 - 2M - S

Tel.: 08123/986-0 Fax: 08123/986-500 www.asm-sensor.com

PMIS3 POSIMAG®
Magnetic Scale Position Sensor

ASM®

Specifications (continued)	Max. pulse frequency fp	50 kHz, 20 kHz, 10 kHz (standard 50 kHz)
	Outputs	A, $\overline{A}$, B, $\overline{B}$, reference pulse Z, $\overline{Z}$, end position signal E, $\overline{E}$, status signal $\overline{ERR}$
	Material of enclosure	Zinc die casting
	Electrical connection	Cable 8 wire, Ø 5 mm, open cable end, 9 pin SUB-D connector at the cable end as option. Max. length of the integrated sensor cable for TTL: 3 m; HTL/TTL24V: 20 m
	Weight (w/o cable and connector)	30 ±5 g
	Protection class (EN 60529)	IP67
	Environmental	
	Shock	EN 60068-2-27:1993, 50 g 6 ms, 100 shocks
	Vibration	EN 60068-2-6:1995, 20 g, 10-2000 Hz, 10 cycles
	EMC	DIN EN 61326
	Temperature	-40 ...+85°C

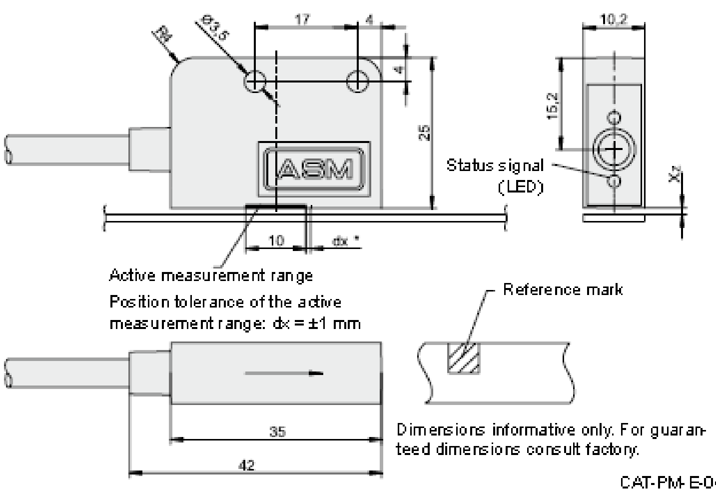
⚠ The subsequent counting device must be able to process the specified maximum pulse frequency of the sensor.

Output signals	Saturation voltage	UH, UL = 0,2 V UH, UL = 0,4 V C_{out} < 10 nF	I_{out} = ±10 mA I_{out} = ±30 mA	(UH = UB - U_{out})
	Short circuit current	ISL, ISH < 800 mA ISL, ISH < 90 mA	(UH, UL = 0 V) (UH, UL = 1,5 V)	
	Rise time	t_r, t_f < 200 ns	with cable length 1 m, 10 % ... 90 %	

Pulse frequency in dependence on the cable length	Load/cable length	Load/pulse frequency fp		
		HTL single ended UB = 24 V	TTL/RS422 differential UB = 5 V *	TTL/24 V UB = 24 V
	Max. output current	50 mA	50 mA	10 mA
	R_{out} min.	500 Ω	100 Ω	500 Ω
	C_{out} max.	10 nF	10 nF	1 nF
	200 m	15 kHz	—	—
	100 m	25 kHz	100 kHz	—
	50 m	50 kHz	200 kHz	50 kHz
	10 m	100 kHz	300 kHz	100 kHz

* = consider the voltage loss of the cable; the excitation voltage 5 V ± 5% of the sensor must be guaranteed.
Note: For longer distances (see specification above) you must use min. 0,5 mm² wire for „Excitation+" and „Excitation GND" (see signal wiring next page), all signal wires must be min. 0,14 mm²!

Outline drawing



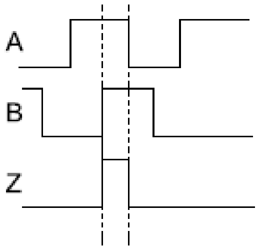
ASM GmbH CAT-PM-E-04 7
Tel.: 08123/986-0 Fax: 08123/986-500 www.asm-sensor.com

PMIS3 POSIMAG®
Magnetic Scale Position Sensor

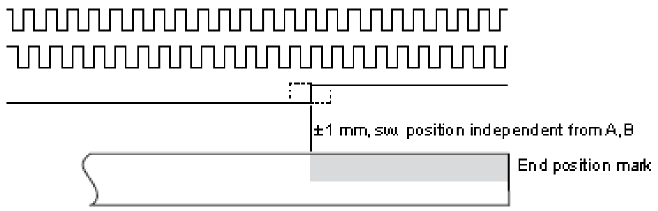
ASM®

Output signals

Option Z1
(Reference pulse)



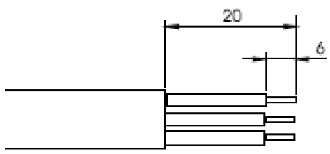
Option Z2
(End position signal)



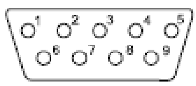
Signal wiring / connection

Signal name					Open cable end Cable colour	Conn. SUB-D, 9 pin pin no.
Option	Z0	Z1	Z2	Z3*		
Excitation +					white	1
Excitation GND (0V)					brown	5
	B	B	B	B	green	2
	A	A	A	A	yellow	3
	$\overline{B}$	$\overline{B}$	$\overline{B}$	$\overline{ERR}$	grey	7
	$\overline{A}$	$\overline{A}$	$\overline{A}$	–	pink	6
	–	Z	$\overline{E}$	Z	blue	4
	–	$\overline{Z}$	E	–	red	8
Shield					black	9

Z = reference pulse
E = end position signal
ERR = status signal, periodical approx. 16 Hz, for side tracking and velocity errors
* = status signal $\overline{ERR}$ available only with HTL (single ended) output



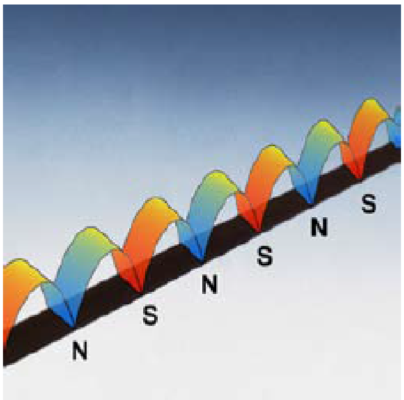
Cable output dimensions



Connector SUB-D (Pin)
View to connector pins

PMIB3 POSIMAG®
Magnetic Scale

ASM®



Magnetic scale PMIB3 for Position Sensor PMIS3

- **Easy splicing**
- **Resistant to moisture and many fluids**
- **Extensive ruggedness against dust etc.**
- **High temperature durability**
- **Magnetic scale with stainless steel base**

The magnetic material is magnetised in defined and even distances and works as a solid measure. Reference marks can be user defined in 4 mm resp. 10 mm steps. The magnetic scale retains its firmness by means of a spring steel base (stainless steel strip CrNi 17 7).

Specifications

Solid measure		Plastic bonded flexible permanent magnet	
Base material		Stainless steel CrNi 17 7 / elastomer	
Masking tape		Stainless steel (non magnetic)	
Measurement ranges		e.g. 100 ... 2500 mm (up to 50 m on request)	
Width		10 mm +0.1 mm / -0.2 mm	
Thickness (w/o masking tape)		1.4 mm +0.1 mm / -0.2 mm	
Thickness (with masking tape)		1.6 mm +0.1 mm / -0.2 mm	
Magnetic period		2 mm	5 mm
Linearity at 25 °C	up to 30 m up to 50 m	±40 µm/m ±80 µm/m	±40 µm/m ±80 µm/m
Reference mark (reference pulse)		max. every 4 mm	max. every 10 mm
Measurement range		must be divisible by 4	must be divisible by 10
Linear thermal expansion coefficient		17×10^{-6} / K	
Operating temperature		-40 ...+100°C	

An unmagnetic masking tape made of stainless steel is available (accessories). The magnetic scale is flexible and can be glued to the surface of a cylinder with a minimum radius of 100 mm and used for angular measurements.

Order code PMIB3

PMIB3 – □ – □ – □ – □ – □

Model name

Magnetic period
20 = 2 mm / 50 = 5 mm

Mounting of the magnetic scale
N = adhesive taping

Measurement range (total length = range + X mm, refer to the table on page 10)
e.g. 100, 500, 1000 ... 2500 mm (up to 50 m on request)
Measurement ranges must be divisible by 4 (resp. by 10)

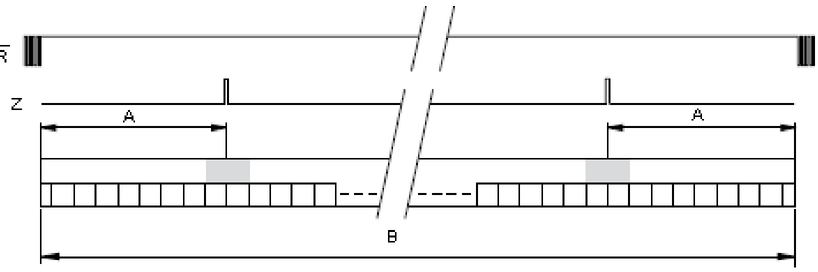
Reference marks/end position marks (optional)
R1 = reference mark on the left / R2 = on the right
E1 = end position mark on the left / E2 = on the right
Additional reference marks every 4 mm (period 2 mm) resp. 10 mm (period 5 mm) from the left

Options
FP = magnetic scale in flat profile
HP = magnetic scale in high profile
AB = masking tape (only with FP + HP)

Order example: PMIB3 - 50 - N - 1500 - R1

PMIS3/PMIB3 POSIMAG®
Magnetic Scale

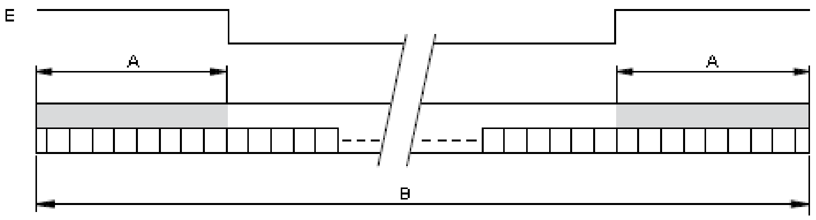
Position of the standard reference marks



Dimensions reference	Magnetic period	Switching position A	Total length B
	2 mm	20.0 ±1 mm	measurement range + 40 mm
	5 mm		
	2 mm with high profile	60.0 ±1 mm	measurement range + 120 mm
	5 mm with high profile		

Additional reference marks every 4 mm (period 2 mm) resp. 10 mm (period 5 mm) from the left h. s.

Position of the end position marks



Dimensions end positions	Magnetic period	Switching position A	Total length B
	2 mm	21.0 ±1 mm	measurement range + 50 mm
	5 mm	22.5 ±1 mm	measurement range + 50 mm
	2 mm with high profile	61.0 ±1 mm	measurement range + 130 mm
	5 mm with high profile	62.5 ±1 mm	measurement range + 130 mm

14.10 Technical data S7 FM-350 counter module

11.2 Technical data

Technical specifications of FM 350-1

Dimensions and weight	
Dimensions W x H x D (mm)	40 x 125 x 120
Weight	approx. 250 g

Current, voltage and power	
Current consumption (from backplane bus)	max. 160 mA
Power loss	typically 4.5 W
Auxiliary voltage 1L+ for the encoder supply Reverse polarity protection	24 V DC (permissible range: 20.4 V to 28.8 V) Yes
Encoder supply	• Current consumption at 1L+ (no-load): max. 20 mA • Encoder supply 24 V – 1L+ -3V – max. 400 mA, short circuit-proof • Encoder supply 5.2 V – 5.2 V ± 2% – max. 300 mA, short circuit-proof • Permissible potential difference between the input (ground) and central grounding busbar of the CPU: 1 V DC
Auxiliary voltage 2L+ for the load power supply Reverse polarity protection	24 V DC (permissible range: 20.4 V to 28.8 V) Yes

Digital inputs	
Low level	-30 V to + 5 V
High level	+11 V to +30 V
Input current	typically 9 mA
Minimum pulse width (max. input frequency)	≥ 2.5 μs (200 kHz), ≥ 25 μs (20 kHz) (programmable)
Input frequency and cable length of asymmetrical encoders (count or digital inputs)	Max. 200 kHz at 20 m length of the cable, shielded
Input frequency and cable length of asymmetrical encoders (count or digital inputs)	Max. 20 kHz at 100 m length of the cable, shielded

Digital outputs	
Supply voltage	2L+ / 2M
Electrical isolation	Yes, against all other circuits, except digital inputs
Output voltage • High signal "1" • Low signal "0"	 min. 2L+ - 1.5 V max. 3 V
Switching current • Rated value • Range	 0.5 A 5 mA to 0.6 A
Rise time	max. 300 µs
Shut-off voltage (inductive)	limited to 2L+ - (45 V to 55 V)
short circuit-proof	Yes

5-V count inputs	
Level	to RS422
Terminating resistor	approx. 220 Ohms
Differential input voltage	min. 1.3 V
Maximum count frequency	500 kHz
Electrical isolation to S7-300 bus	No
Input frequency and cable length of symmetrical 5-V incremental encoder	max. 500 kHz at 32 m length of the cable, shielded
Input frequency and cable length of symmetrical 24-V incremental encoder	max. 500 kHz at 100 m length of the cable, shielded

24-V count inputs	
Low level	-30 V to +5 V
High level	+11 V to +30 V
Input current	typically 9 mA
Minimum pulse width (max. count frequency)	≥ 2.5 µs (200 kHz), ≥ 25 µs (20 kHz) (assignable)
Electrical isolation to S7-300 bus	No
Input frequency and cable length of asymmetrical encoders (count or digital inputs)	Max. 200 kHz at 20 m length of the cable, shielded
Input frequency and cable length of asymmetrical encoders (count or digital inputs)	Max. 20 kHz at 100 m length of the cable, shielded

14.11 PSA tag nomenclature

GRUPO DE INSTRUMENTACIÓN Y DATOS, i&D

Nomenclatura de la INSTRUMENTACIÓN a seguir en los proyectos de la PSA

Se sigue en lo posible la NORMA ANSI/ISA–5.1–1984 (R1992)

El TAG será la definición normalizada del nombre asignado a un instrumento, señal, dato o variable y estará compuesta por diferentes conceptos separados por guiones. Todos ellos podrán ser empleados o no según criterios establecidos en el proyecto.

TAG = Descriptor - área - número - ext - equipo - acción - ruta

Descriptor. Describe la funcionalidad y el tipo de señal/variable/instrumento según códigos ISA recogidos en las tablas adjuntas (hasta un máximo de 6 letras)

- Emplearemos como primera letra <first letter /measured&variable>

P- presión/vacío
T- temperatura
F- caudal/flujo
L- nivel
D- densidad
R- radiación
W- peso/fuerza
Z- posición/dirección
S- velocidad/frecuencia
Y- estado/evento/presencia
K- tiempo/hora
E- Voltaje/tensión
I – Intensidad
J- Potencia
V- Vibración
H- manual
A-análisis
B- combustión
U- multivariable/cálculos/
C, D, G, M, N, O- otros a elección del usuario (humedad, precipitación, impedancia, conductividad, volumen, densidad,...)

- Emplearemos como segunda letra <modifier>

D- diferencial
Q- Totalizador
X- componente A, directa (radiación solar), eje/dirección X
Y- componente B, global (radiación solar), eje/dirección Y
Z- componente C, difusa (radiación solar), eje/dirección Z

- Emplearemos como tercera letra <Readout/pasive function>

A (entradas digitales) para alarmas, fallos, mal funciones...
E (entradas analógicas) para elemento, sensor primario (termopares, PT100, NTC, termopilas...)
I Indicador local
G Indicador de vidrio
L Indicador luminoso
W termopozo
O placa de orificio, restricción

- Emplearemos como cuarta letra <output function> las siguientes:

S (entradas digitales) para estados, interruptores, ...
Y (salidas digitales) para órdenes, activación relés/contactores,...
T (entradas analógicas), transmisor (mA, V,...)
N (variables transmitidas por wireless)
C (salidas analógicas) control, punto de consigna, ...
K (variables procedentes de otros sistemas de control o DAS)
V Válvula
Z Actuador, driver

Table 1 — Identification Letters

	FIRST-LETTER (4)		SUCCEEDING-LETTERS (3)		
	MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	Analysis (5,19)		Alarm		
B	Burner, Combustion		User's Choice (1)	User's Choice (1)	User's Choice (1)
C	User's Choice (1)			Control (13)	
D	User's Choice (1)	Differential (4)			
E	Voltage		Sensor (Primary Element)		
F	Flow Rate	Ratio (Fraction) (4)			
G	User's Choice (1)		Glass, Viewing Device (9)		
H	Hand				High (7, 15, 16)
I	Current (Electrical)		Indicate (10)		
J	Power	Scan (7)			
K	Time, Time Schedule	Time Rate of Change (4, 21)		Control Station (22)	
L	Level		Light (11)		Low (7, 15, 16)
M	User's Choice (1)	Momentary (4)			Middle, Intermediate (7,15)
N	User's Choice (1)		User's Choice (1)	User's Choice (1)	User's Choice (1)
O	User's Choice (1)		Orifice, Restriction		
P	Pressure, Vacuum		Point (Test) Connection		
Q	Quantity	Integrate, Totalize (4)			
R	Radiation		Record (17)		
S	Speed, Frequency	Safety (8)		Switch (13)	
T	Temperature			Transmit (18)	
U	Multivariable (6)		Multifunction (12)	Multifunction (12)	Multifunction (12)
V	Vibration, Mechanical Analysis (19)			Valve, Damper, Louver (13)	
W	Weight, Force		Well		
X	Unclassified (2)	X Axis	Unclassified (2)	Unclassified (2)	Unclassified (2)
Y	Event, State or Presence (20)	Y Axis		Relay, Compute, Convert (13, 14, 18)	
Z	Position, Dimension	Z Axis		Driver, Actuator, Unclassified Final Control Element	

5.3

Table 2 — Typical Letter Combinations

First-Letters	Initiating or Measured Vaiable	Controllers				Readout Devices		Swithces and Alarm Devices*			Transmitters			Solenoids, Relays, Computing Devices	Primary Element	Test Point	Well or Probe	Viewing Device, Glass	Safety Device	Final Elemen
		Recording	Indicating	Blind	Self-Actuated Control Valves	Recording	Indicating	High**	Low	Comb	Recording	Indicating	Blind							
A	Analysis	ARC	AIC	AC		AR	AI	ASH	ASL	ASHL	ART	AIT	AT	AY	AE	AP	AW			AV
B	Burner/Combustion	BRC	BIC	BC		BR	BI	BSH	BSL	BSHL	BRT	BIT	BT	BY	BE		BW	BG		BZ
C	User's Choice																			
D	User's Choice																			
E	Voltage	ERC	EIC	EC		ER	EI	ESH	ESL	ESHL	ERT	EIT	ET	EY	EE					EZ
F	Flow Rate	FRC	FIC	FC	FCV, FICV	FR	FI	FSH	FSL	FSHL	FRT	FIT	FT	FY	FE	FP		FG		FV
FQ	Flow Quantity	FQRC	FQIC			FQR	FQI	FQSH	FQSL			FQIT	FQT	FQY	FQE					FQV
FF	Flow Ratio	FFRC	FFIC	FFC		FFR	FFI	FFSH	FFSL						FE					FFV
G	User's Choice																			
H	Hand		HIC	HC						HS										HV
I	Current	IRC	IIC			IR	II	ISH	ISL	ISHL	IRT	IIT	IT	IY	IE					IZ
J	Power	JRC	JIC			JR	JI	JSH	JSL	JSHL	JRT	JIT	JT	JY	JE					JV
K	Time	KRC	KIC	KC	KCV	KR	KI	KSH	KSL	KSHL	KRT	KIT	KT	KY	KE					KV
L	Level	LRC	LIC	LC	LCV	LR	LI	LSH	LSL	LSHL	LRT	LIT	LT	LY	LE		LW	LG		LV
M	User's Choice																			
N	User's Choice																			
O	User's Choice																			
P	Pressure/ Vacuum	PRC	PIC	PC	PCV	PR	PI	PSH	PSL	PSHL	PRT	PIT	PT	PY	PE	PP			PSV, PSE	PV
PD	Pressure, Differential	PDRC	PDIC	PDC	PDCV	PDR	PDI	PDSH	PDSL		PDRT	PDIT	PDT	PDY	PE	PP				PDV
Q	Quantity	QRC	QIC			QR	QI	QSH	QSL	QSHL	QRT	QIT	QT	QY	QE					QZ
R	Radiation	RRC	RIC	RC		RR	RI	RSH	RSL	RSHL	RRT	RIT	RT	RY	RE		RW			RZ
S	Speed/Frequency	SRC	SIC	SC	SCV	SR	SI	SSH	SSL	SSHL	SRT	SIT	ST	SY	SE					SV
T	Temperature	TRC	TIC	TC	TCV	TR	TI	TSH	TSL	TSHL	TRT	TIT	TT	TY	TE	TP	TW		TSE	TV
TD	Temperature, Differential	TDRC	TDIC	TDC	TDCV	TDR	TDI	TDSH	TDSL		TDRT	TDIT	TDT	TDY	TE	TP	TW			TDV
U	Multivariable					UR	UI							UY						UV
V	Vibration/Machinery Analysis					VR	VI	VSH	VSL	VSHL	VRT	VIT	VT	VY	VE					VZ
W	Weight/Force	WRC	WIC	WC	WCV	WR	WI	WSH	WSL	WSHL	WRT	WIT	WT	WY	WE					WZ
WD	Weight/Force, Differential	WDRC	WDIC	WDC	WDCV	WDR	WDI	WDSH	WDSL		WDRT	WDIT	WDT	WDY	WE					WDZ
X	Unclassified																			
Y	Event/State/Presence		YIC	YC		YR	YI	YSH	YSL				YT	YY	YE					YZ
Z	Position/Dimension	ZRC	ZIC	ZC	ZCV	ZR	ZI	ZSH	ZSL	ZSHL	ZRT	ZIT	ZT	ZY	ZE					ZV
ZD	Gauging/Deviation	ZDRC	ZDIC	ZDC	ZDCV	ZDR	ZDI	ZDSH	ZDSL		ZDRT	ZDIT	ZDT	ZDY	ZDE					ZDV

Note: This table is not all-inclusive.
*A, alarm, the annunciating device, may be used in the same fashion as S, switch, the actuating device.

**The letters H and L may be omitted is the undefined case.

Other Possible Combinations:

FO	(Restriction Orifice)	PFR	(Ratio)
FRK, HIK	(Control Stations)	KQI	(Running Time Indicator)
FX	(Accessories)	QQI	(Indicating Counter)
TJR	(Scanning Recorder)	WKIC	(Rate-of-Weight-Loss Controller)
LLH	(Pilot Light)	HMS	(Hand Momentary Switch)

EJEMPLOS DE TAG:

- **Entradas digitales/estados operativos/variables booleanas de entrada/instrumentos DI**

PSH-HTF-205. Instrumento Presostato de alta del área HTF número 205 del área HTF
LISLL-BP-001. Instrumento indicador con interruptor de muy bajo nivel nº 001 del área BOP
YA-BP-EA01. Estado de alarma del aero EA01 situado en área BOP
YS-BP-HTR01-on. Confirmación de marcha del calentador HTR01 en área BOP
YK-BP-FCV001-lc-Sm. Estado local de la válvula de control de flujo FCV001 situada en área BOP y transmitida por línea serie/modbus por un equipo remoto
ZKL-BP-PCV019-Sm. Posición limite cerrada de válvula de control de presión PCV019 situada en BOP y transmitida por línea serie/modbus por un equipo remoto
EAKH-BP-P02-Sm. Alarma de sobretensión de la bomba P02 situada en el área BOP y transmitida por línea serie/modbus por un equipo remoto
FAKH-BP-FT007-wl-P. Alarma de alto caudal generada por el PLC procedente del equipo FT007 situado en el área BOP vía wireless.

- **Salidas digitales/órdenes/comandos/variables booleanas de salida**

NY-BP-P01-on. Orden de marcha cableada a la bomba P01 situada en área BOP
NK-BP-EA02-rs-P. Orden de reset desde el sistema de control al aero EA02 situado en área BOP
TIC-BP-EA01-m_on-P. Orden de mando local del PID desde el sistema de control del aero EA01 situado en área BOP
NY-SFS-LC89-st. Orden digital cableada de Abatimiento del colector 89 del campo Sur.

- **Entradas analógicas/variables/instrumentos de medida AI**

TE-SFS-101-F. Instrumento y elemento de temperatura del área SFS número 101 (cross section) elemento F
FT-BP-007-mf. Caudal másico del instrumento transmisor 007 del área BOP (señal cableada 4-20mA)
UT-BP-001-d
RXE-BP-401. Instrumento Pirheliómetro de radiación solar directa situado en área BOP
ZQK-BP-FCV001-cl-Sm. Contador número de maniobras contactor de cierre de la válvula FVC100 situada en área BOP y transmitida por línea serie/modbus
UK-BP-FT017-mx-P. Lectura de la Pendiente mx en sistema de control para el escalado de la señal de caudal del instrumento FT007 situado en área BOP
JQK-BP-P01-ac-Sm. Energía activa consumida por la bomba P01 situada en el área BOP y transmitida por línea serie/modbus
RXK-BP-MET-wl-Sm. Radiacción solar directa vía wireless procedente de la estación MET del área BOP transmitida por línea serie Modbus
ZK-SFS-LC901-pos-Sm. Posición angular de colector 901 del campo solar Sur transmitida por línea serie/Modbus
UK-SFS-LC99-dz-Sm. Cálculo de la distancia zenital del vector solar realizada por el colector LC99 del campo solar SUR transmitida por línea serie/modbus
Transmisores/instrumentos de campo:
FN-BP-007-vf-Sm. Caudal volumétrico del transmisor wireless multivariable 007 del área BOP transmitida por línea serie/modbus
FN-BP-007-d-Sm o DK-BP-FT007-wl-Sm. Valor de densidad calculada por un equipo remoto FT007 del área BOP transmitida vía wireless por línea serie/modbus

- **Salidas analógicas/variables/comandos/puntos de consigna**

SC-BP-AE01. Consigna de velocidad del ventilador del EA01 situado en área BOP
UK-BP-FT017-mx-P. Escritura en sistema de control de la Pendiente mx para el escalado de la señal de caudal del instrumento FT007 situado en área BOP

TIC-BP-EA01-ti-P. Escritura en sistema de control del Tiempo integral del lazo PID del areo EA01 situado en área BOP

DEFINICIÓN DE TAG EN LOS PROYECTOS DE LA PSA

- **Señales/variables físicas I/O & instrumentos:**

DI: DIGITAL INPUTS
PSH, PSL, PSHH, PSLL, PIS, presostatos
PDSH, PDSL, PDSHH, PDSLL, PIDS, presión diferencial
TSH, TSL, TSHH, TSLL, TIS, termostatos
LSH, LSL, LSHL, LSLL, interruptores de nivel
FSH, FSL, FSHH, FSLL, interruptores de caudal
ZSH, ZSL, ZSHH, ZSLL, finales de carrera, interruptores de posición
EA, EAH, EAL, disparos, protecciones eléctricas, térmicos...
YS, YSH, YSL, estados operativos (ON/OFF, LOCAL/REMOTO, ESTADOS COLECTOR,...)
YA, YAH, YAL, estados de alarma (FALLO, DISPARO, ALARMA,...)
HS, HA, interruptor manual

DO: DIGITAL OUTPUTS
YY, YYH, YYL –*equipo-acción* > Orden a relé/solenoide/válvula
NY, NYH, NYL–*equipo-acción* > Orden a equipo o controlador (bombas, variadores de frecuencia, actuadores válvulas, motores, aeros, calefactores, controles locales helióstatos/captadores...)
Equipo: ver lista abajo
Acción: Ver lista abajo

AI: ANALOG INPUTS (0-20mA, 4-20mA, 0-10V, 0-10mV...)
PT, PIT, PE, PDT, PDIT, elementos y transmisores de presión
TT, TIT, TE, TDE, TDT, elementos y transmisores de temperatura
FT, FIT, FE, elementos y transmisores de caudal
LT, LIT, transmisores de nivel
RT, RE, RXT, RYT, RZT, RXE, RYE, RZE transmisores y elementos de radiación (radiómetros, piranómetros, pirheliómetros,...)
ST, SIT, SE, elementos y transmisores de velocidad y frecuencia (anemómetros, motores,...)
ZT, ZIT, ZE, elementos y transmisores de posición (veletas, válvulas,...)
JT, JIT, JE, elementos y transmisores de potencia eléctrica.
JQT, JQIT, transmisores de energía
ET, EIT, EE, elementos y transmisores de voltaje
IT, IIT, IE, elementos y transmisores de intensidad
KT, KIT, KE, elementos y transmisores de tiempo (relojes, cronos, calendario...)
VT, VIT, VE, elementos y transmisores de vibraciones
WT, WIT, WDT, WE, elementos y transmisores de peso y fuerza (probetas y galgas extensiométricas)
AT, AIT, AE, elementos y transmisores de análisis (ph, redox, cromatografía,...)
C, D, G, M, N, O, letras libres por el usuario (humedad, precipitación, impedancia, conductividad, densidad,...)

AO: ANALOG OUTPUTS (0-20mA, 4-20mA, 0-10V ...)
ZC-*equipo* -> control de posición (posicionadores, actuadores válvulas,...)

SC-*equipo* -> control de velocidad/frecuencia (variadores de frecuencia motores,…)
JC-*equipo* -> control de potencia/consumo (calefactores eléctricos,…)
EC-*equipo* -> control de tensión
IC-*equipo* -> control de intensidad
NC-*equipo* -> *control a otros equipos (controladores, set point, drivers,…)*

Equipo: ver lista abajo

- **Indicación local:**

TI, TG, termómetros
PI, PDI manómetros
FI, FG, indicadores de caudal, rotámetros de cristal
LI, LG, indicadores de nivel, nivel de cristal

- **Variables no físicas I/O:**

Estas variables no proceden de instrumentos físicos y son gestionadas por otros sistemas de control o equipos remotos que intercambian información.
Son generadas/intercambiadas/recepcionadas por sistemas u otros equipos comunicados con el sistema de control/SCADA del proyecto. Las vías de comunicación para el intercambio de esta información puede ser por línea serie (RS232, RS422, RS485,…) u otras medios físicos como Ethernet, wireless,…
Los datos serán intercambiados bajo los protocolos más empleados en la PSA como son: Modbus, Ethernet, wireless HART, OPC,…
En el descriptor será empleada la letra **K** como <output function> para indicar que procede de un sistema de control diferente o de un equipo remoto autónomo.

Equipos, componentes:

ZZ posicionadores, actuadores válvulas
SZ servos, drivers, variadores de frecuencia motores
TW, termopozo, poceto
FO, placa de orificio
HV, válvula manual
PSV, válvula de seguridad
PCV, válvula de control de presión
TCV, válvula de control de temperatura
FCV, válvula de control de flujo
CV, válvula de control
PIC, TIC, FIC, lazos de control PID
TK, tanques, depósitos
EA, intercambiadores, refrigeradores, aeros
HTR, calentadores, calderas
P, bombas
M, motores
EG, Generador eléctrico (Generador de emergencia, grupo electrógeno, diésel,…)
UPS, sistema de alimentación ininterrupida
LVSB, Cuadro de distribución de Baja tensión (Low Voltage SwitchBoard)
CB, cuadro de control
EB, cuadro de distribución eléctrica
NA, Analizador de redes eléctricas, (Network analyzer)
PLC, autómatas/controladores
SLC, Controles locales de Helióstatos/captadores
SCC, Control Central de Helióstatos/Captadores
GW, Gateway wireless
GS, Estación de gases (N2, air, O,…)
WTP, Planta de tratamiento de agua
MET, Estación Meteorológica

Acción

Actuación/estados operativos de equipos:
on= marcha,
off= paro,
rs= reset,
op= open/abierto,
cl= close/cerrado
st= parado,
mn= manual,
lc= local,
rm= remote,
lr= local/remoto
ctr= control
Actuación/estados operativos de colectores solares:
st= stow/abatimiento,
tr= track/seguimiento,
de= desteer/desfase,
lc= mando local
mn= posición manual
Información adicional de variables de colectores
pos= posición angular
cmd= consigna angular
dz= distancia zenital
Información adicional de variables
fq= frecuencia,
sp= velocidad
ds= densidad
mf= caudal masico
mx= pendiente escala (y=mx+n)
n= término independiente escala
avg= media,
max= máxima,
min= mínima,
Bol= Booleana,
Int= entera,
Real= real,
Información adicional de variables eléctricas:
in =entrada,
out= salida,
main= principal,
iUPS= entrada sai,
oUPS= salida sai
ac= activa,
re= reactiva,
ap= aparente
p1= fase 1,
p1n= fase 1 y neuto,
p23= fases 1 y 2,
pf = factor de potencia,
Información adicional de procedencia
pu =pump/bomba,

bat= batería,
inv= inversor,
gen= generador,
byp= Bypass,
fan =ventilador,
com=comunicaciones,
wl= wireless
op= fibra óptica

Ruta

W. wired/cableado (por defecto)
WL. Wireless/inalámbrico
S. Serie (RS232, RS422, RS485, Modbus, CAN, profibus,...)
(Sm = serial Modbus, Sp= serial profibus, Sc= serial Can...)
H. HART
L. LAN
O. OPC
F. fibra óptica
P. PLC/DAS

14.12 Signal list

In the following an extract of the signal list is presented. Some cells are hidden to allow a readable presentation in the A4 format

	A	F	G	H	I	Q	Z	AA	AD	AE	AF
3	Data Channel					Range					
4	no.	tag	type	description	IO type	electrical	going to component	cable type	PSA nomenclature	Module	Adress
5	1	HTF circuit	absolute pressure	suction side absolute	AI	4-20 mA	PLC	two wire	PE-HTF-01-W	7	AI 400
6	2	HTF circuit	absolute pressure	pressure side absolute	AI	4-20 mA	PLC	two wire	PE-HTF-02-W	7	AI 402
7	3	HTF circuit	temperature	motor, HTF pump	AI		VFD ASC400	4 wire	TT-HTF-01-W		
8	4	HTF circuit	temperature	Bearing, HTF pump	AI	t100 T2, 4 wir	PLC	4 wire	TT-HTF-02-W	9	AI 352
9	5	HTF circuit	temperature	lubricating oil, HTF pump	AI		PLC	4 wire	TT-HTF-03-W	9	AI 356
10	6	HTF circuit	temperature	fluid temp. heater outlet	AI	4-20 mA	PLC	4 wire transmitter	TT-HTF-04-W	8	AI 416
11	7	HTF circuit	temperature	tube surface temp. heater 1	AI	mV	PLC	2 wire	TT-HTF-05-W	5	AI 384
12	8	HTF circuit	temperature	tube surface temp. heater 2	AI	mV	PLC	2 wire	TT-HTF-06-W	5	AI 386
13	9	HTF circuit	temperature	tube surface temp. heater 3	AI	mV	PLC	2 wire	TT-HTF-07-W	5	AI 388
14	10	HTF circuit	temperature	tube surface temp. heater 4	AI	mV	PLC	2 wire	TT-HTF-08-W	5	AI 390
15	11	HTF circuit	temperature	tube surface temp. heater 5	AI	mV	PLC	2 wire	TT-HTF-09-W	5	AI 392
16	12	HTF circuit	temperature	tube surface temp. heater 6	AI	mV	PLC	2 wire	TT-HTF-10-W	5	AI 394
17	13	HTF circuit	power	power heater 1	DO	VDC	PLC		EY-HTF-01-W	18	DQ 14.0
18	14	HTF circuit	power	power heater 2	DO	VDC	PLC		EY-HTF-02-W	18	DQ 14.1
19	15	HTF circuit	power	power heater 3	DO	VDC	PLC		EY-HTF-03-W	18	DQ 14.2
20	16	HTF circuit	power	power heater 4	DO	VDC	PLC		EY-HTF-04-W	18	DQ 14.3
21	17	HTF circuit	power	power heater 5	DO	VDC	PLC		EY-HTF-05-W	18	DQ 14.4
22	18	HTF circuit	power	power heater 6	DO	VDC	PLC		EY-HTF-06-W	18	DQ 14.5
23	19	HTF circuit	differential pressure	orifice plate differential pressure	AI	4-20 mA	PLC	2 wire	PE-HTF-03-W	7	AI 404
24	20	HTF circuit	absolute pressure	absolute pressure test facility outlet	AI	4-20 mA	PLC	2 wire	PE-HTF-04-W	7	AI 406
25	21	kinematics	multi axis load cell	force/torque REPA No. 1 east top	USB	-5V (output 6Ni card/Panel P(		x poliges cable			
26	22	kinematics	multi axis load cell	force/torque REPA No. 2 est bottom	USB	-5V (output 6Ni card/Panel P(		x poliges cable			
27	23	kinematics	multi axis load cell	force/torque REPA No. 3 west top	USB	-5V (output 6Ni card/Panel P(		x poliges cable			
28	24	kinematics	multi axis load cell	orce/torque REPA No. 4 west bottor	USB	-5V (output 6Ni card/Panel P(		x poliges cable			
29	25	kinematics	temperature	:emperature multi force east top 1.1	AI	1000 Ohm	PLC	4 wire			
30	26	kinematics	temperature	temperature multi force east top 1.2	AI	1000 Ohm	PLC	4 wire			
31	27	kinematics	temperature	temperature multi force east top 1.3	AI	1000 Ohm	PLC	4 wire			
32	28	kinematics	temperature	temperature multi force east top 1.4	AI	1000 Ohm	PLC	4 wire			
33	119	kinematics	temperature	nperature multi force east bottom 2	AI	1000 Ohm	PLC	4 wire			
34	120	kinematics	temperature	mperature multi force east bottom 2	AI	1000 Ohm	PLC	4 wire			
35	121	kinematics	temperature	mperature multi force east bottom 2	AI	1000 Ohm	PLC	4 wire			
36	122	kinematics	temperature	mperature multi force east bottom 2	AI	1000 Ohm	PLC	4 wire			
37	123	kinematics	temperature	emperature multi force west top 3.1	AI	1000 Ohm	PLC	4 wire	TT-HTF-11-W	9	AI 360
38	124	kinematics	temperature	temperature multi force west top 3.2	AI	1000 Ohm	PLC	4 wire	TT-HTF-12-W	9	AI 362
39	125	kinematics	temperature	temperature multi force west top 3.3	AI	1000 Ohm	PLC	4 wire	TT-HTF-13-W	9	AI 364
40	126	kinematics	temperature	temperature multi force west top 3.4	AI	1000 Ohm	PLC	4 wire	TT-HTF-14-W	9	AI 366
41	127	kinematics	temperature	nperature multi force west bottom 4	AI	1000 Ohm	PLC	4 wire			
42	128	kinematics	temperature	mperature multi force west bottom 4	AI	1000 Ohm	PLC	4 wire			
43	129	kinematics	temperature	mperature multi force west bottom 4	AI	1000 Ohm	PLC	4 wire			
44	130	kinematics	temperature	mperature multi force west bottom 4	AI	1000 Ohm	PLC	4 wire			
45	29	HTF circuit	absolute pressure	absolute pressure, N2 tubing	AI	4-20 mA	PLC	2 wire	PE-HTF-05-W	7	AI 408
46	30	HTF circuit	level switch	level switch expansion vessel (top)	DI	8/16 mA	PLC	2 wire	FA-HTF-01-W	15	DI 8.0
47	31	HTF circuit	level switch	:vel switch expansion vessel (botton	DI	8/16 mA	PLC	2 wire	FA-HTF-03-W	15	DI 8.1
48	32	HTF circuit	temperature	nperature expansion vessel 1 (liqui	AI	4 - 20 mA	PLC	4 wire transmitter	TT-HTF-15-W	8	AI 418
49	33	HTF circuit	temperature	emperature expansion vessel 2 (gas	AI	4 - 20 mA	PLC	4 wire transmitter	TT-HTF-16-W	8	AI 420
50	34	HTF circuit	Position	set value valve	AO	4 - 20 mA	PLC	4 wire transmitter	ZC-HTF-01-W	16	AQ 326
51	35	HTF circuit	Position	set value valve	AO	4 - 20 mA	PLC	4 wire transmitter	ZC-HTF-02-W	17	AQ 336
52	36	HTF circuit	Position	valve position 1	AI	4 - 20 mA	PLC	2 wire	ZT- HTF-15-W	7	AI 410
53	37	HTF circuit	Position	valve position 2	AI	4 - 20 mA	PLC	2 wire	ZT-HTF-16-W	7	AI 414
54	38	HTF circuit	Position	ition valve closed (HTF bypass valv	DI	0 - 24 V	PLC	2 wire	ZS-HTF-01-W	15	DI 8.2
55	39	HTF circuit	Position	on valve opend (HTF kinematics va	DI	0 - 24 V	PLC	2 wire	ZS-HTF-02-W	15	DI 8.3
56	40	kinematics	limit switch	inductive sensor rotation negative	DI	24V - 0V	PLC	3 wire	ZS-CI-01-W	14	DI 6.4
57	41	kinematics	limit switch	inductive sensor rotation positive	DI	24V -0V	PLC	3 wire	ZS-CI-02-W	14	DI 6.5
58	42	kinematics	position	magnetic tape sensor rotation	AI	24V	_C counter mody 6 wires used (9 u		ZT-CI-11-W	4	o 271 (In
59	43	kinematics	limit switch	nductive sensor translation negative	DI	24V - 0V	PLC	3 wire	ZS-CI-04-W	14	DI 6.6
60	44	kinematics	limit switch	inductive sensor translation positive	DI	24V -0V	PLC	3 wire	ZS-CI-05-W	14	DI 6.7
61	45	kinematics	rotary encoder	rotary encoder -translation	AI	4-20 mA	PLC	4 wire	ZS-CI-06-W	8	AI 424
62	46	HTF circuit	temperature	HTF temperature pump inlet	AI	4-20 mA	PLC	4 wire transmitter	TT-HTF-17-W	8	AI 422
63	47	kinematics	temperature	hydraulic oil temperature	AI	rt list Weber hydraulic		not known, put 4 wi	TT-CI-13-W	7	AI 412
64	48	kinematics	level switch	hydraulic oil level	DI	rt list Weber hydraulic			LA-CI-03-W	15	DI 8.7
65	49	kinematics	'endnet outdoor IP Ca	Video Camera	Ethernet	V oder über P net switch/ Pan		POE			
66	50	kinematics	'endnet outdoor IP Ca	Video Camera	Ethernet	V oder über P	Panel PC	POE			
67	51	kinematics	keylock	keylock switch	DI	0-24V	PLC		HS-CI-01-W	15	DI 9.0
68	52	kinematics	Signal light	Ready Signal light	DO	0 - 24 V	PLC			18	DQ 13.6
69	53	kinematics	Signal light	Disorder Signal light	DO	0 - 24 V	PLC			18	DQ 13.7
70	54	kinematics	rotation left	push button rotation left	DI	0-24V	PLC		HS-CI-02-W	15	DI 9.1
71	55	kinematics	rotation right	push button rotation right	DI	0-24V	PLC		HS-CI-03-W	15	DI 9.2
72	56	kinematics	translation forward	push button translation forward left	DI	0-24V	PLC		HS-CI-04-W	15	DI 9.3
73	57	kinematics	translation backward	ush button translation backward rigt	DI	0-24V	PLC		HS-CI-05-W	15	DI 9.4
74	131	kinematics	relay	reset safety relay	DO	realy (230 V)	PLC	2 wire	YY-ESD-01-W	19	DQ 52.2
75	58	kinematics	emergency switch	Emergency push button 6 pieces	DI	0 - 24 V	PLC		YA-CI-03-W	14	DI 6.2
76	59	kinematics	noke detector 4 piece	ESD, when smoke	DI	230V/ 50Hz	PLC		YA-CI-04-W	14	DI 6.3
77	60	kinematics	signal horn	Sounds when Alarm	DO		PLC		YY-CI-04-W	18	DQ 13.5
78	61	HTF circuit	leakage sensor	leakage / swim sensor	DI	0-24V	PLC		FA-HTF-02-W	14	DI 7.0
79	62	HTF circuit	leakage sensor	conrad leakage sensor	DI	0-24V	PLC		FA-HTF-02-W	14	DI 7.0
80	63	HTF circuit	leakage sensor	conrad leakage sensor	DI	0-24V	PLC		FA-HTF-02-W	14	DI 7.0
81	64	kinematics	3-way valve	Y1 3-way valve	DO	0-24V @ 1.3 /	PLC	3 wire	PY-CI-01-W	18	DQ 56.0
82	65	kinematics	3-way valve	Y2 3-way valve	DO	0-24V @ 1.3 /	PLC	3 wire	PY-CI-02-W	18	DQ 56.1
83	66	kinematics	3-way valve	Y3 3-way valve	DO	0-24V @ 1.3 /	PLC	3 wire	PY-CI-03-W	18	DQ 56.2
84	67	kinematics	3-way valve	Y4 3-way valve	DO	0-24V @ 1.3 /	PLC	3 wire	PY-CI-04-W	18	DQ 56.4
85	68	kinematics	3-way valve	Y5 3-way valve	DO	0-24V @ 1.3 /	PLC	3 wire	PY-CI-05-W	18	DQ 56.5
86	69	kinematics	3-way valve	Y6 3-way valve	DO	0-24V @ 1.3 /	PLC	3 wire	PY-CI-06-W	18	DQ 56.6
87	70	HTF circuit	Power	HTF pump on/off (2K1 -> 2Q1)	DO	0 - 24 V	ncy Converter /	1 wire	EY-HTF-08-W	18	DQ 12.0
88	136	nitrogen	2-way valve	Y7 2-way valve nitrogen (vent)	DO	0-230 V	PLC		PY-HTF-07-W	18	DQ 52.0
89	71	HTF circuit		setpoint HTF pump	AO	4 - 20 mA	PLC		SC-HTF-01-W	16	AQ 320
90	135	nitrogen	2-way valve	Y8 2-way valve nitrogen (input)	DO	0-230 V	PLC		PY-HTF-08-W	18	DQ 52.1

	A	F	G	H	I	Q	Z	AA	AD	AE	AF
91	72	HTF circuit		Start/Stop VFD HTF pump	DO	0- 24 V	PLC		EY-HTF-09-W	18	DQ 12.7
92	118	kinematics	relative preasure	e transmitter hydraulic unit translatic	AI	4 - 20 mA	PLC	2 wire	PE-CI-02-W	8	AI 430
93	73	kinematics	kinematics	CW/CCW (reset?)VFD HTF pump	DO	0- 24 V	PLC		YY-HTF-05-W	18	DQ 13.0
94	117	kinematics	relative preasure	ıre transmitter hydraulic unit rotatior	AI	4 - 20 mA	PLC	2 wire	PE-CI-01-W	8	AI 428
95	74	HTF circuit		ENRUN enable run (hardware enable	DO	0- 24 V	PLC		YY-HTF-09-W	internal	internal
96	75	HTF circuit		Actual value HTF pump	AI	4 - 20 mA	PLC		ST-HFT-01-W	8	AI 426
97	76	HTF circuit		error HTF pump	DI	0- 24 V	PLC		YS-HTF-01-W	14	DI 4.0
98	77	HTF circuit		running HTF pump	DI	0- 24 V	PLC		YS-HTF-02-W	14	DI 4.1
99	78	HTF circuit		thermistor protection HTF pump	DI	0- 24 V	ıncy Converter ACS400		TS-HTF-01-W		
100	79	HTF circuit	kinematics	/d oil cooler pump on/off (2K2 -> 2Q	DO	0- 24 V	PLC	1 wire	EY-CI-10-W	18	DQ 12.1
101	80	HTF circuit	kinematics	On/Off travelling crane	DO	0- 24 V	PLC		EY-HTF-11-W	witch in circuitlayout	
102	81	HTF circuit	kinematics	rotation on/off (5K1->5Q1)	DO	0- 24 V	PLC	1 wire	EY-CI-12-W	18	DQ 12.3
103	82	kinematics	kinematics	setpoint rotation	AO	4 - 20 mA	PLC		SC-CI-03-W	16	AQ 324
104	deleted see below										
105	84	kinematics	kinematics	CW/CCW Servo Motor	DO	0- 24 V	PLC		YY-HTF-07-W		
106	85	kinematics	kinematics	deactivate recovery barrier	DO	0- 24 V	PLC				
107	86	kinematics	kinematics	safe turn moment	DO	0- 24 V	PLC		YY-HTF-08-W		
108	87	kinematics	kinematics	servo motor running (OSD00)	DI	0- 24 V	PLC		YS-CI-03-W	14	DI 5.1
109	88	kinematics	kinematics	error servo motor (OSD01)	DI	0- 24 V	PLC		YS-CI-04-W	14	DI 5.2
110	111	kinematics	kinematics	nalog input servo controller + (ISA0-	AO	+/- 10 V	PLC		servo ISA0+	oint rotation (No 82)	
111	112	kinematics	kinematics	ınalog input servo controller - (ISA0-	AO	+/- 10 V	PLC		servo ISA0-		
112	113	kinematics	kinematics	rvo (digital input servo controller 1 (	DO	0- 24 V	PLC	1 wire	YY-CI-09-W	18	DQ 14.6
113	114	kinematics	kinematics	ligital input servo controller 2 (ISD01	DO	0- 24 V	PLC	1 wire	servo ISD01	:ted / no DO ports left	
114	115	kinematics	kinematics	ᴾO servo (powe stage hardware ena	DO	0- 24 V	PLC	1 wire	YY-CI-05-W	18	DQ 15.1
115	116	kinematics	kinematics	ISDSH servo (safe stop)	DO	0- 24 V	PLC	1 wire	YY-CI-06-W	internal	internal
116	89	HTF circuit	kinematics	translation on/off (4K2->4Q2)	DO	0- 24 V	PLC		EY-CI-13-W	18	DQ 12.4
117	90	kinematics	kinematics	setpoint translation	AO	4 - 20 mA	PLC	1 wire	SC-CI-02-W	16	AQ 322
118	91	kinematics	kinematics	start translation (VFD)	DO	0- 24 V	PLC	1 wire	ZY-CI-14-W	18	DQ 12.5
119	92	kinematics	kinematics	CW/CCW translation (VFD)	DO	0- 24 V	PLC	1 wire	ZY-CI-15-W	18	DQ 13.2
120	93	kinematics	kinematics	⁼D translation (powe stage hardwar	DO	0- 24 V	PLC	1 wire	YY-CI-07-W	18	DQ 15.2
121	94	kinematics	kinematics	translation ready	DI	0- 24 V	PLC	1 wire	YS-CI-05-W	14	DI 5.6
122	95	kinematics	kinematics	stop translation	DI	0- 24 V	PLC	1 wire	YS-CI-06-W	14	DI 5.4
123	96	kinematics	kinematics	reach setpoint translation	DI	0- 24 V	PLC	1 wire	YS-CI-07-W	14	DI 5.5
124	132	kinematics	kinematics	ISDSH VFD translation (safe stop)	DO	0- 24 V	PLC	1 wire	YY-CI-08-W	internal	internal
125	97	kinematics	kinematics	Actual value translation	AI		PLC	1 wire	ZT-HTF-02-W	8	AI 428
126	98	HTF circuit	Power	reset selectivity modul 1	DO	0- 24 V	PLC	1 wire	YY-HTF-09-W	18	DQ 13.3
127	99	HTF circuit	Power	protection 230 V contol (8F3)	DI	0- 24 V	PLC	1 wire	ES-HTF-01-W	14	DI 6.1
128	100	HTF circuit	Power	Main Break Switch	DI	0- 24 V	PLC	1 wire	ES-HTF-02-W	14	DI 4.7
129	101	HTF circuit	Power	protection VFD HTF (2F1)	DI	0- 24 V	PLC	1 wire	ES-HTF-03-W	14	DI 4.3
130	102	HTF circuit	Power	ırotection hyd oil cool pump M3 (2F5	DI	0- 24 V	PLC	1 wire	ES-CI-04-W	14	DI 4.4
131	103	HTF circuit	Power	Travelling Crane Switch On/Off	DI	0- 24 V	PLC	1 wire	ES-HTF-05-W	tch in cuirquit layout. S	
132	104	HTF circuit	Power	protection servo rotation (5F1)	DI	0- 24 V	PLC	1 wire	ES-CI-06-W	14	DI 5.0
133	105	HTF circuit	Power	protection VFD translation (4F2)	DI	0- 24 V	PLC	1 wire	ES-CI-07-W	14	DI 5.3
134	106	HTF circuit	Power	error aux ventilator M4 (hydraulic)	DI	0- 24 V	PLC	1 wire	ES-HTF-08-W	14	DI 5.7
135	107	HTF circuit	Power	error heater (protection)	DI	0- 24 V	PLC	1 wire	ES-HTF-09-W	14	DI 6.0
136	108	HTF circuit	Power	Error Light/Controll Voltage/	DI	0- 24 V	PLC	1 wire	ES-HTF-10-W	agramm nor arrangem	
137	109	EMS	EMS	Emergency Alarm	DI	0- 24 V	EMS Switch		YS-HTF-08-W	ıcy switch signal No.:	
138	110	HTF circuit	Power	reset selectivity modul 2	DO	0- 24 V	PLC	1 wire	YY-HTF-10-W	18	DQ 13.4
139	133	kinematics	kinematics	H servo diagnose safe stop (feedba	DI	0- 24 V	PLC	1 wire	YA-CI-05-W	15	DI 10.0
140	134	kinematics	kinematics	'D translation diagnose safe stop (fe	DI	0- 24 V	PLC	1 wire	YA-CI-06-W	15	DI 10.1
141											

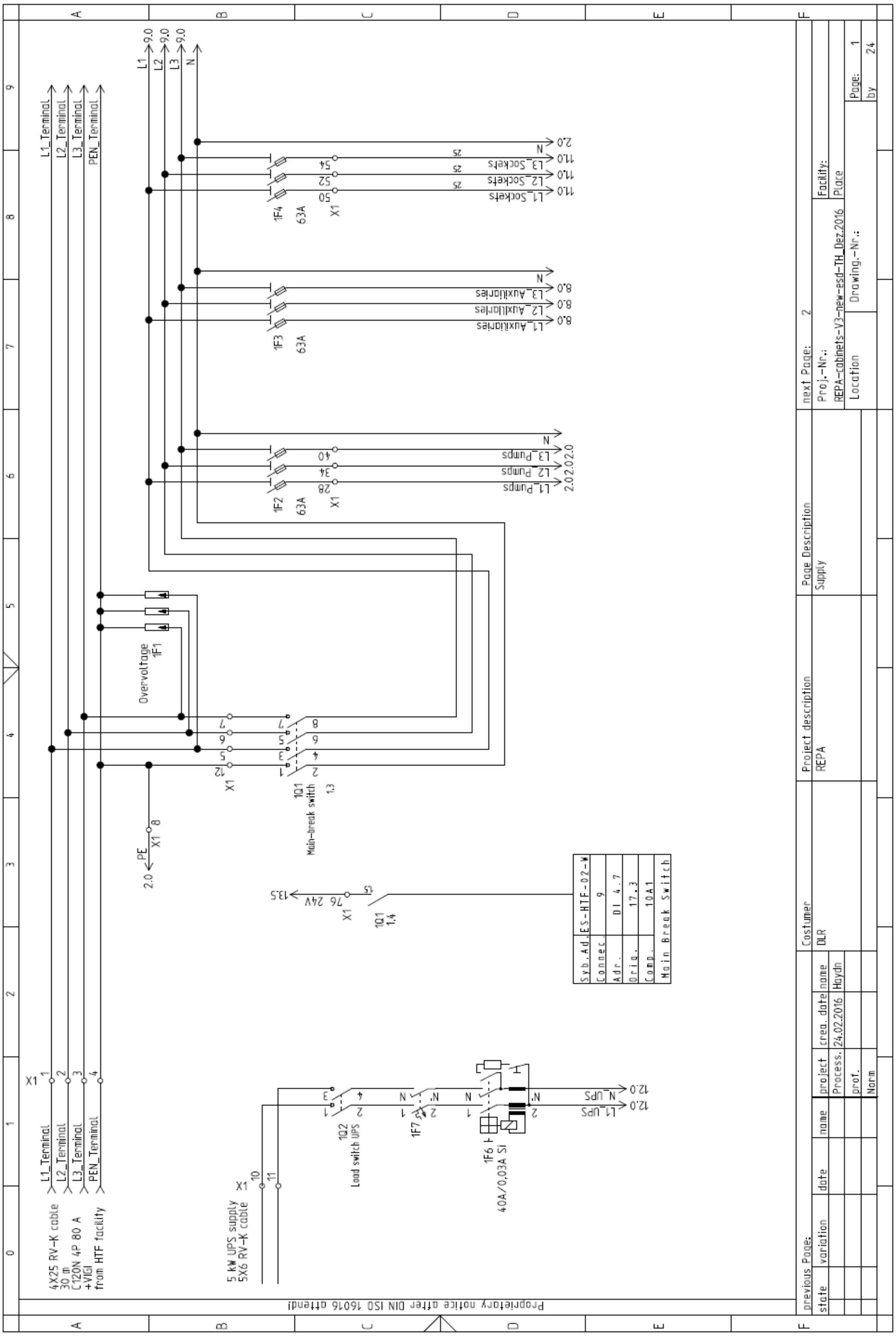
14.13 Example of inclinometer

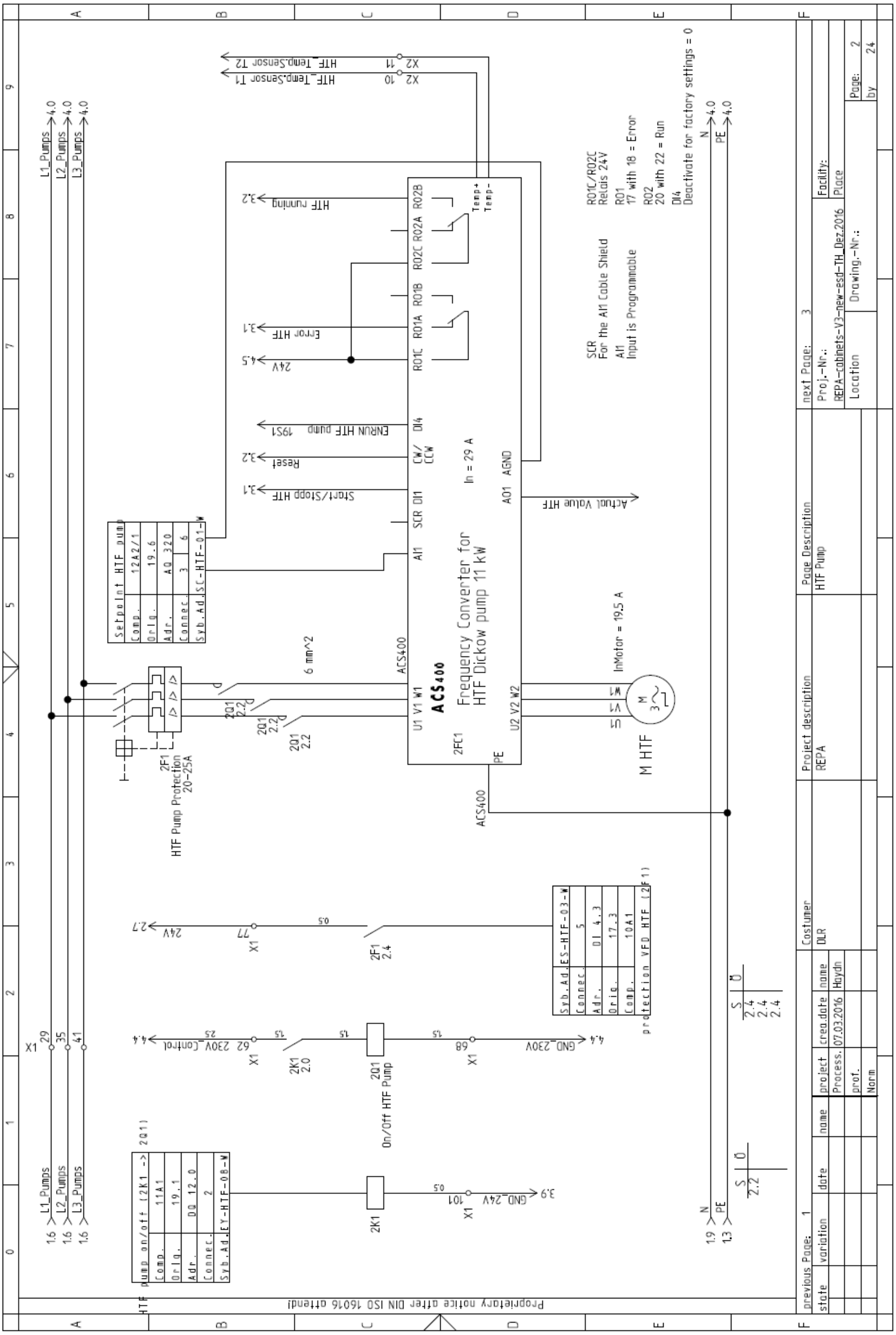
Figure 39: Inclinometer [24]

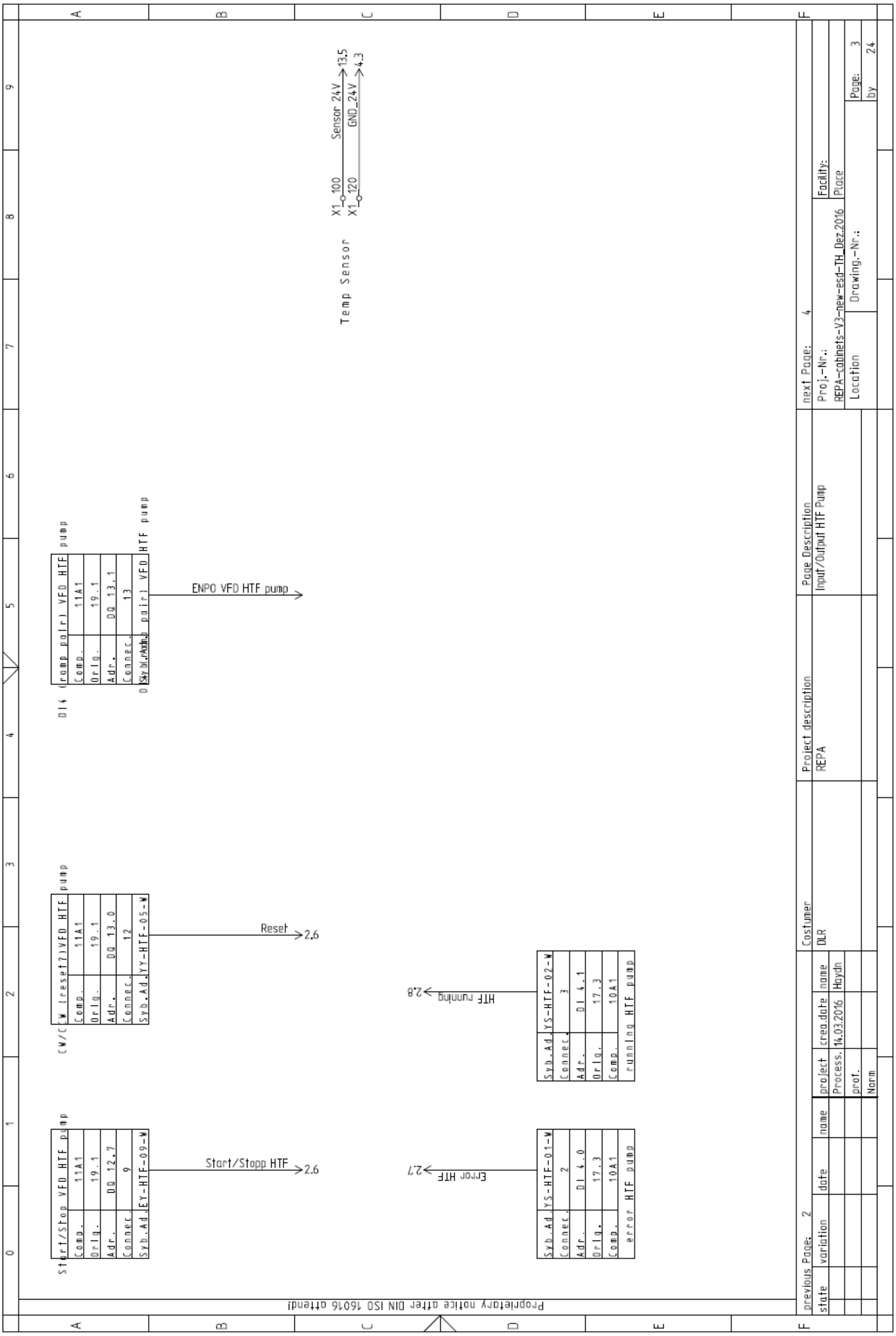
- Inclination Range: ±80° (2D) or 360° (1D)
- Accuracy: 0.1° and Resolution: 0.01°
- Analog, CANopen, J1939, RS232, DeviceNet, SSI
- Operating Temperature: -40°C to +85°C
- Protection Class up to IP69K

[24]

14.14 Circuit diagram

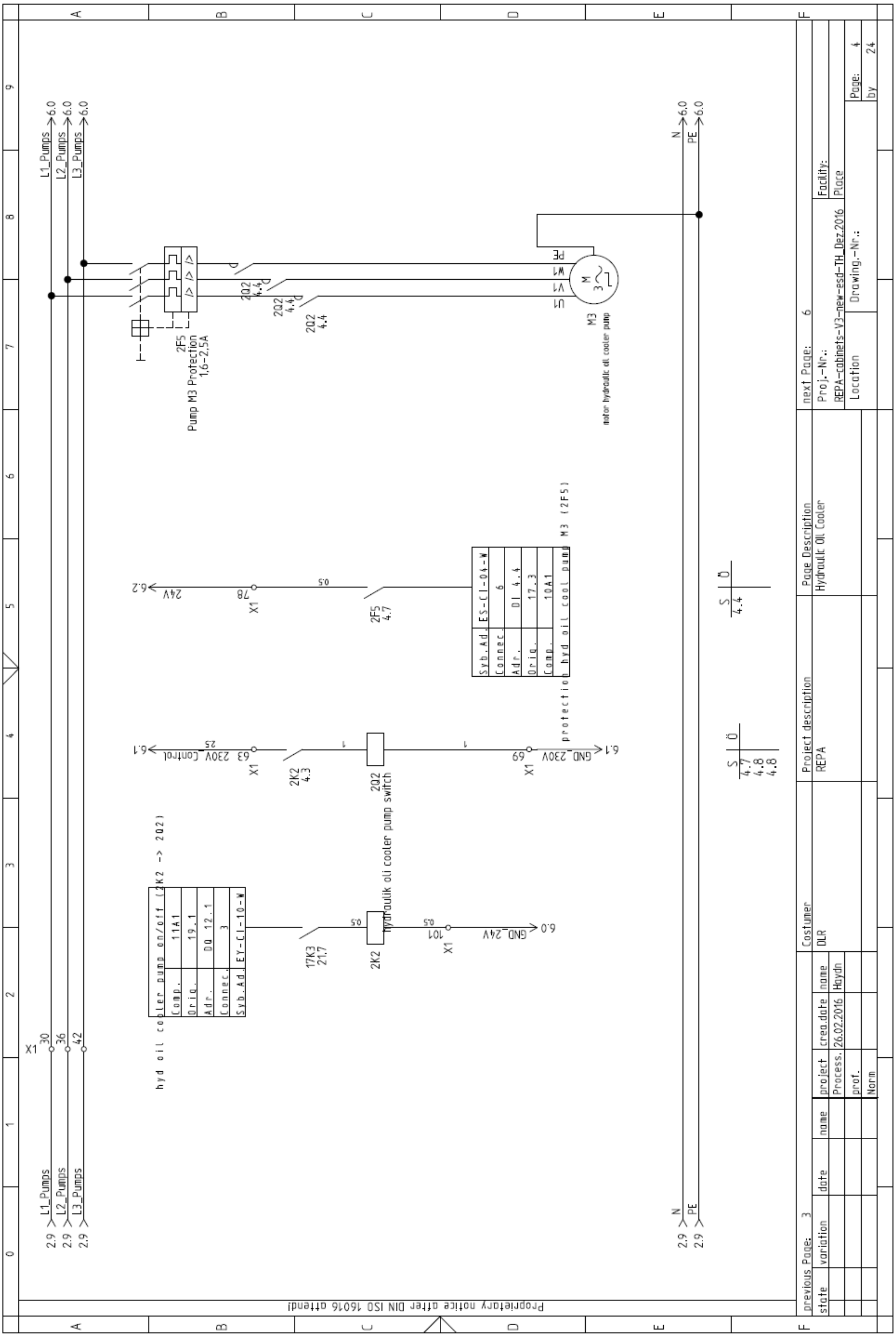


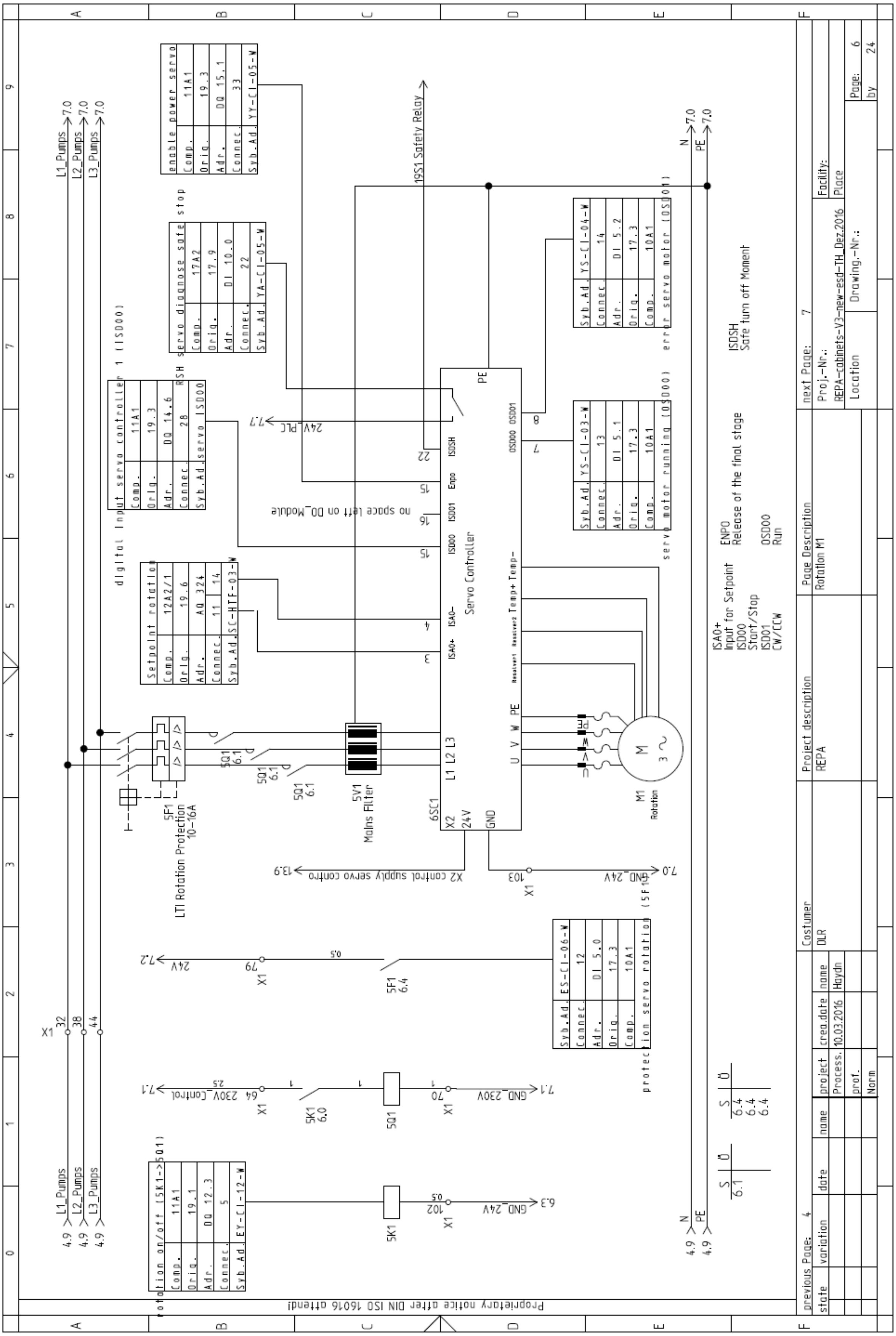

ACS400
Frequency Converter for
HTF Dickow pump 11 kW
In = 29 A
InMotor = 19,5 A
M HTF
2F1
HTF Pump Protection
20-25A
2Q1
On/Off HTF Pump
2K1
6 mm^2
SCR
For the AI1 Cable Shield
AI1
Input is Programmable
RO1C/RO2C
Relais 24V
RO1
17 with 18 = Error
RO2
20 with 22 = Run
DI4
Deactivate for factory settings = 0
HTF_Temp.Sensor T1
HTF_Temp.Sensor T2
HTF running
Error HTF
Reset
Start/Stopp HTF
ENRUN HTF pump
Actual Value HTF
L1_Pumps
L2_Pumps
L3_Pumps
Proprietary notice after DIN ISO 16016 attend!
Page Description
HTF Pump
Project description
REPA
Costumer
DLR
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Facility:
Place
Location
Drawing.-Nr.:
Page: 2
by 24
crea.date 07.03.2016
name Haydn


Temp Sensor
X1_100
X1_120
Sensor 24V
GND_24V
13.5
4.3
ENPO VFD HTF pump
Reset
2.6
Start/Stopp HTF
2.6
HTF running
2.8
Error HTF
2.7
Proprietary notice after DIN ISO 16016 attend!
previous Page: 2
next Page: 4
state
variation
date
name
project
Process.
crea.date
14.03.2016
name
Haydn
prof.
Norm
Costumer
DLR
Project description
REPA
Page Description
Input/Output HTF Pump
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Facility:
Place
Location
Drawing.-Nr.:
Page: 3
by 24

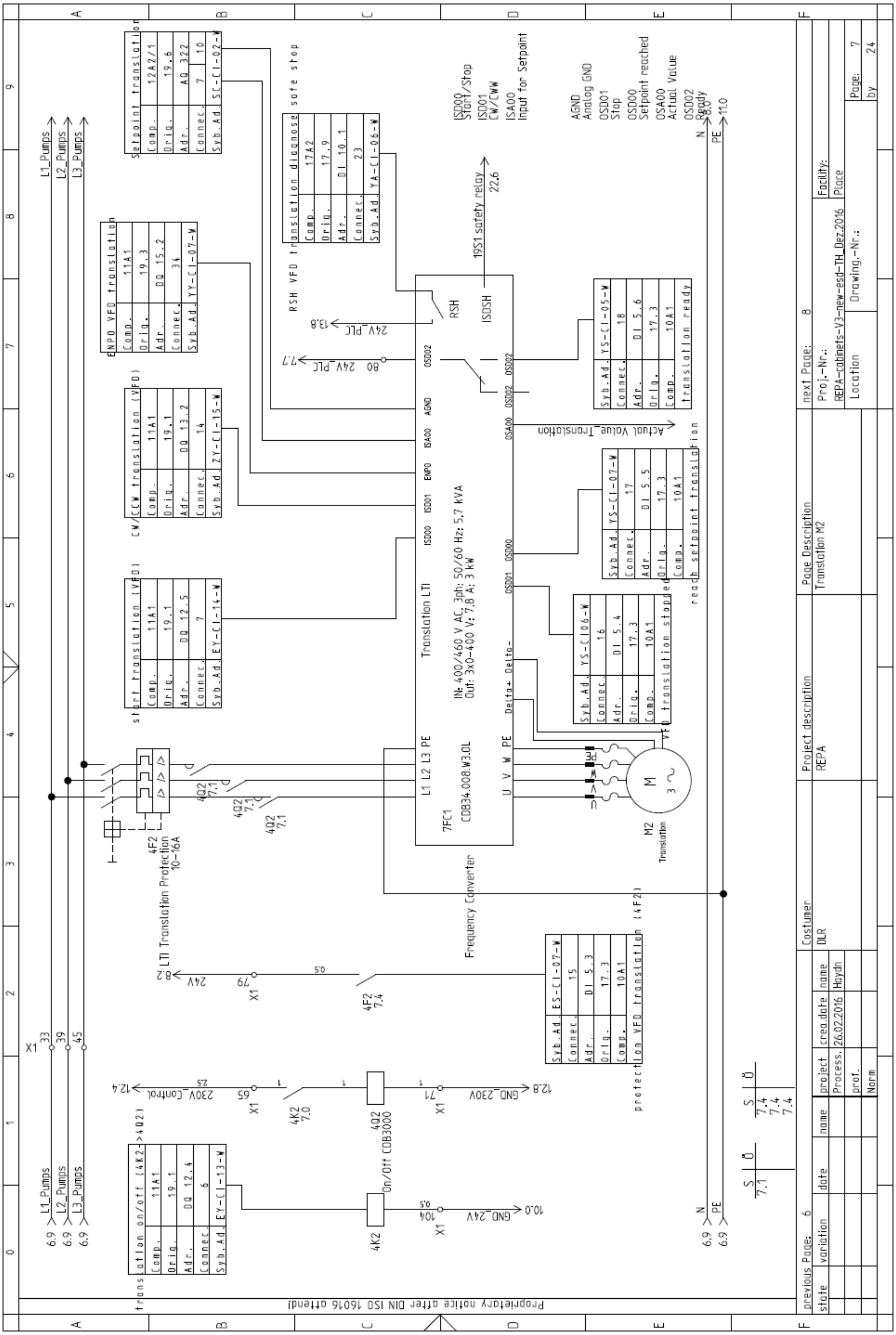
hochschule mannheim

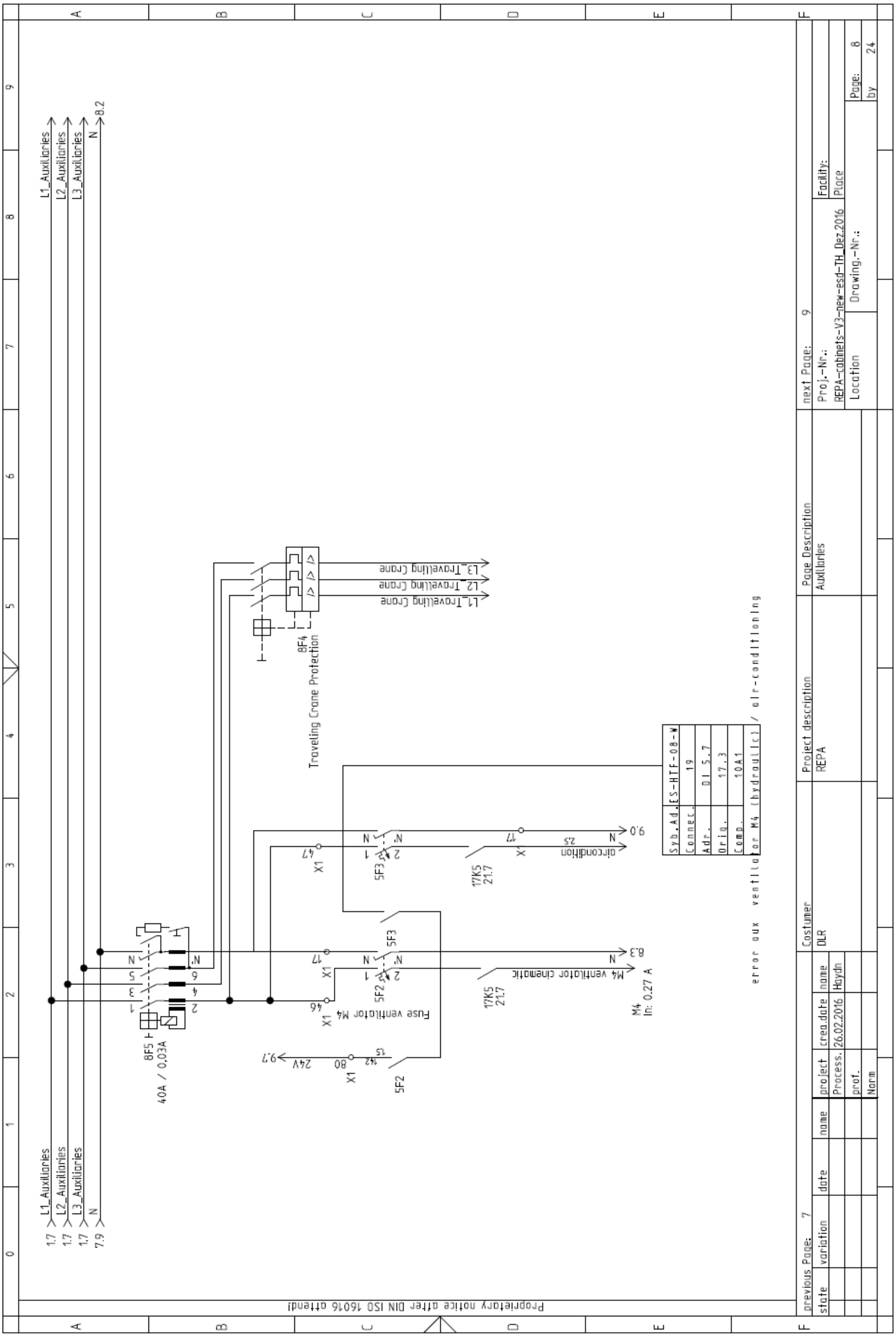
DLR

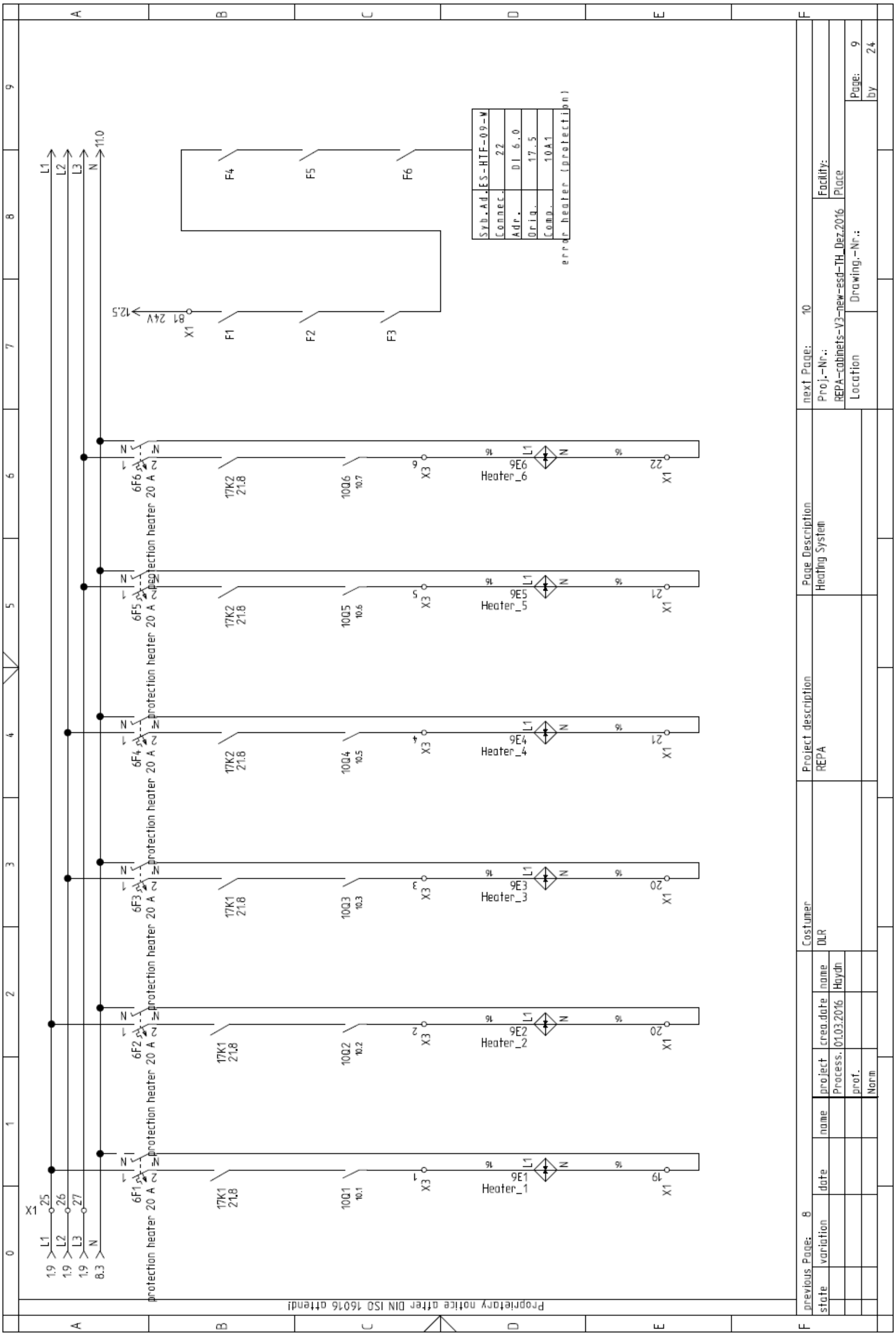


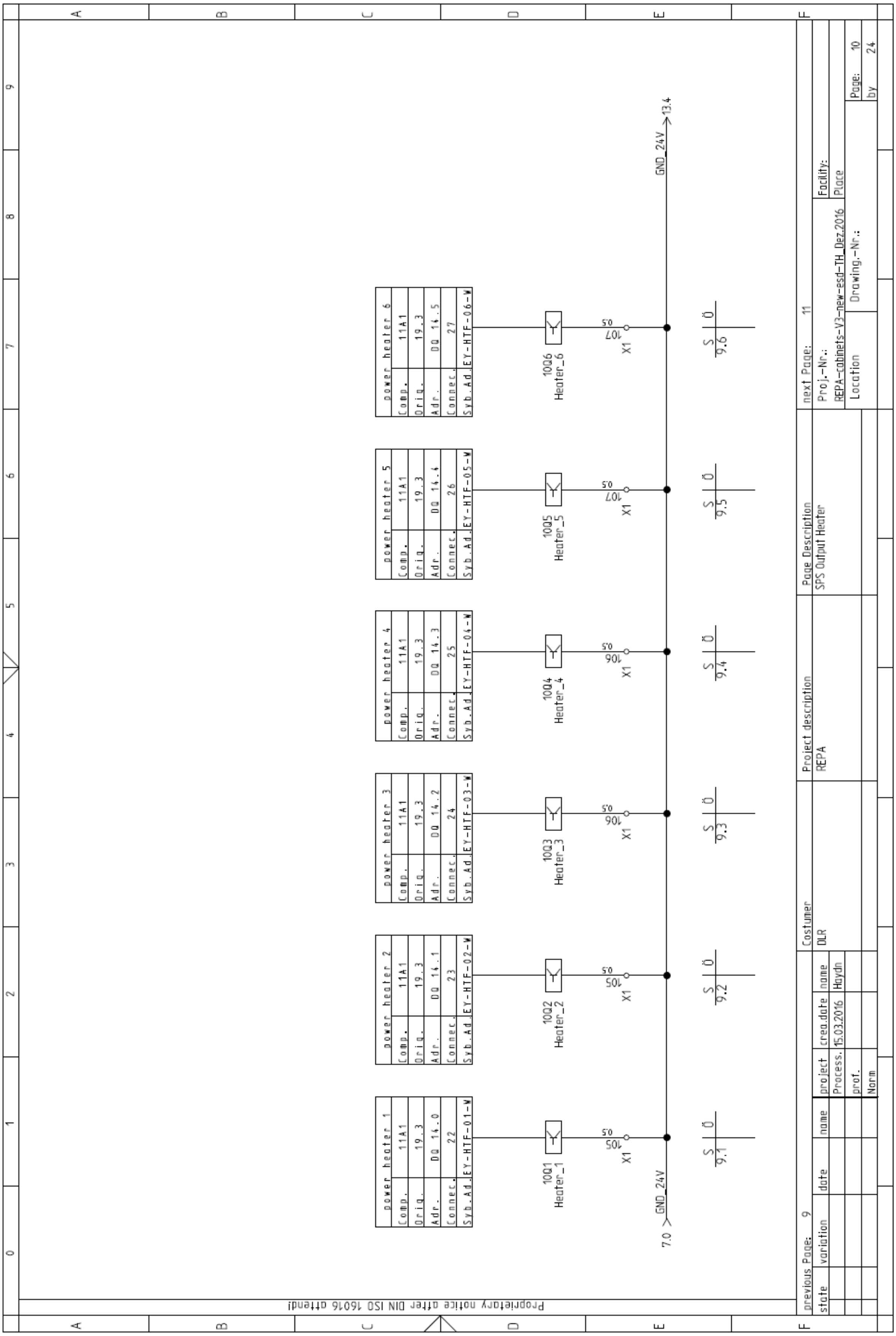


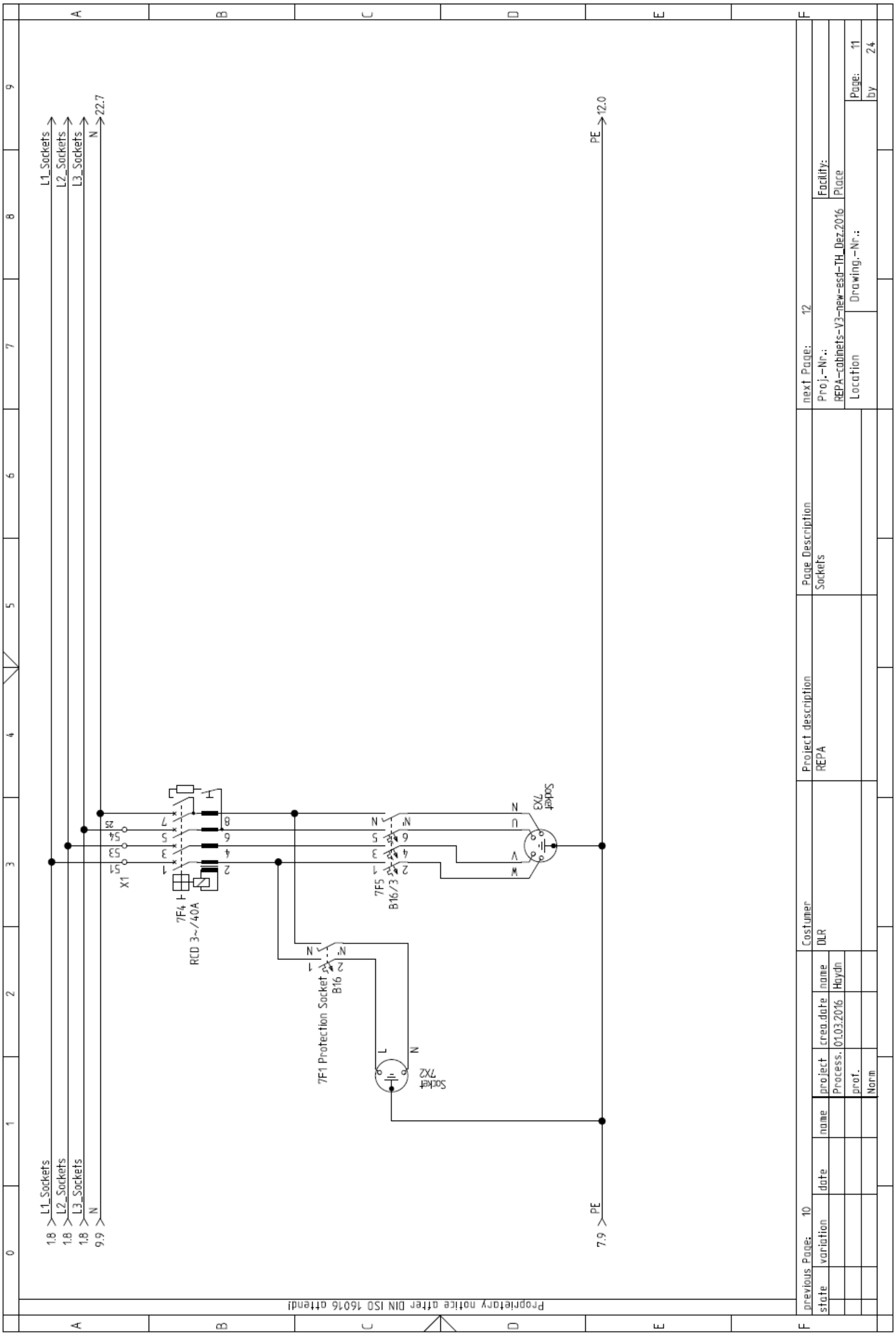
Servo Controller
6SC1
Mains Filter
5V1
5F1
LTI Rotation Protection
10-16A
M1
Rotation
19S1 Safety Relay
no space left on DO_Module
X2 control supply servo contro
Proprietary notice after DIN ISO 16016 attend!
ISA0+
Input for Setpoint
ISD00
Start/Stop
ISD01
CW/CCW
ENPO
Release of the final stage
OSD00
Run
ISDSH
Safe turn off Moment
Project description
REPA
Page Description
Rotation M1
Costumer
DLR
crea.date
10.03.2016
name
Haydn
REPA-cabinets-V3-new-esd-TH_Dez.2016
Page: 6
by 24

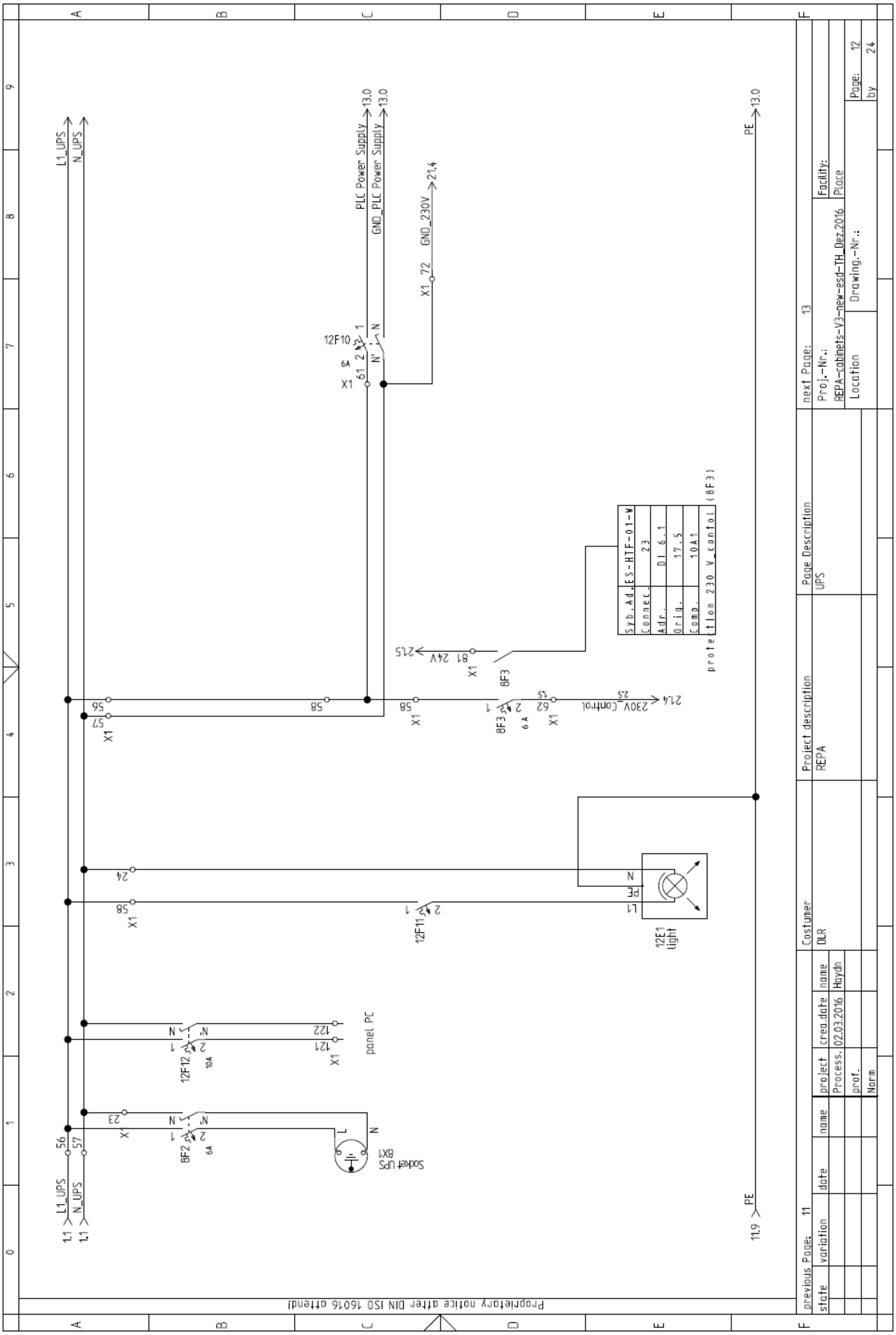

Translation LTI
IN: 400/460 V AC, 3ph; 50/60 Hz; 5,7 kVA
Out: 3x0–400 V; 7,8 A; 3 kW
7FC1
CDB34.008.W3.0L
Frequency Converter
LTI Translation Protection
10–16A
M2
Translation
19S1 safety relay
22.6
RSH
ISDSH
ISD00 Start/Stop
ISD01 CW/CWW
ISA00 Input for Setpoint
AGND Analog GND
OSD01 Stop
OSD00 Setpoint reached
OSA00 Actual Value
OSD02 Ready
Actual Value_Translation
L1_Pumps
L2_Pumps
L3_Pumps
On/Off CDB3000
Proprietary notice after DIN ISO 16016 attend!
Project description
REPA
Page Description
Translation M2
Costumer
DLR
REPA-cabinets-V3-new-esd-TH_Dez.2016
26.02.2016
Haydn
Page: 7
by 24

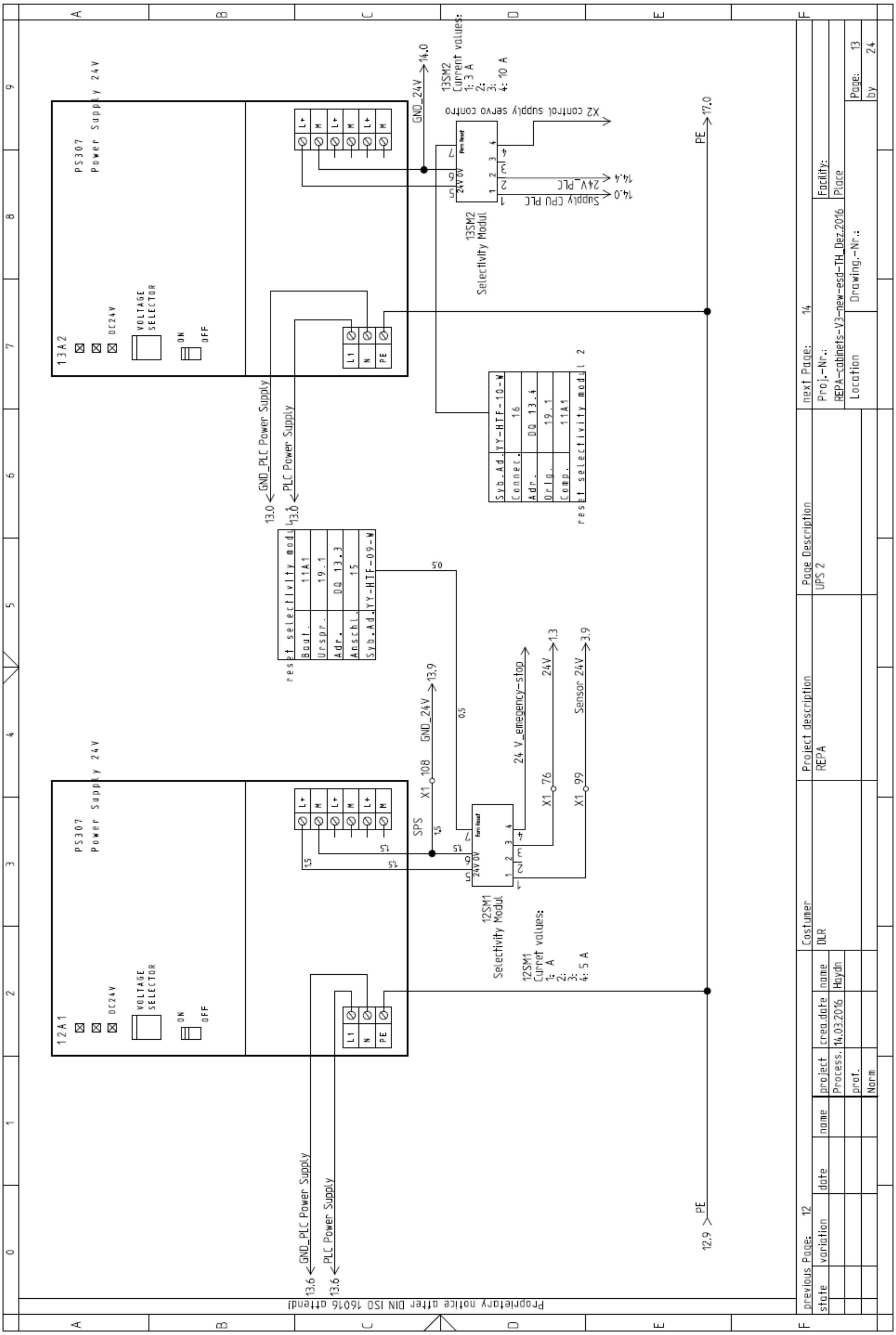

L1_Auxiliaries
L2_Auxiliaries
L3_Auxiliaries
N
8.2
1.7
7.9
8F5
40A / 0,03A
8F4
Traveling Crane Protection
L1_Traveling Crane
L2_Traveling Crane
L3_Traveling Crane
5F3
5F2
17K5
21.7
X1
Fuse ventilator M4
M4 ventilator cinematic
M4
In: 0.27 A
aircondition
9.0
8.3
9.7
24V
error aux ventilator M4 (hydraulic) / air-conditioning
Syb.Ad. ES-HTF-08-W
Connec. 19
Adr. DI 5.7
Orig. 17.3
Comp. 10A1
Proprietary notice after DIN ISO 16016 attend!
previous Page: 7
state
variation
date
name
project
Process.
prof.
Norm
crea.date 26.02.2016
name Haydn
Costumer DLR
Project description REPA
Page Description Auxiliaries
next Page: 9
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Location
Drawing.-Nr.:
Facility:
Place
Page: 8
by 24

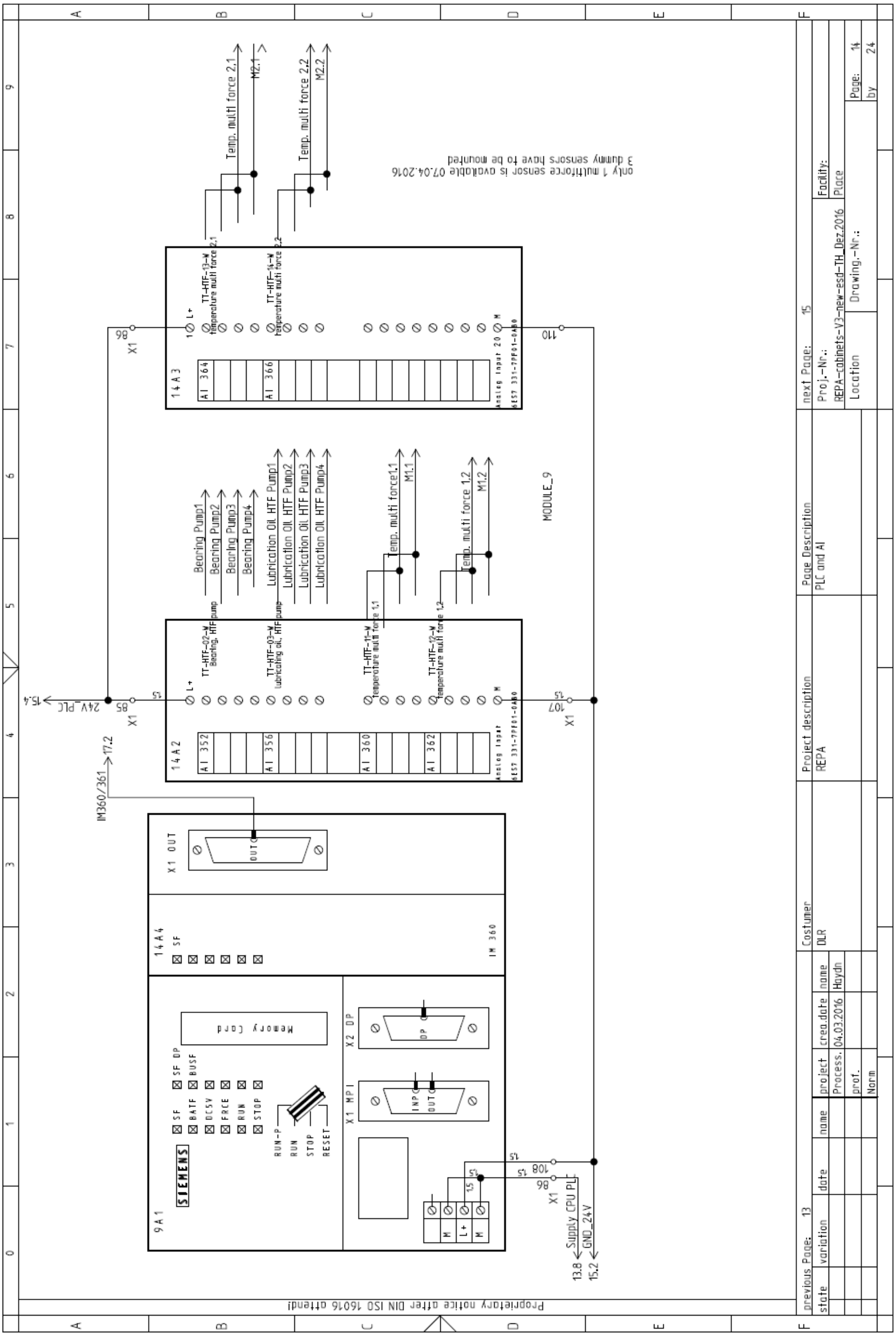

Heater_1
Heater_2
Heater_3
Heater_4
Heater_5
Heater_6
protection heater 20 A
Page Description
Heating System
Project description
REPA
Costumer
DLR
Proprietary notice after DIN ISO 16016 attend!


power heater 1
Comp. 11A1
Orig. 19.3
Adr. DQ 14.0
Connec. 22
Syb.Ad. EY-HTF-01-W
1OQ1
Heater_1
X1
105
0.5
S | Ö
9.1
power heater 2
Comp. 11A1
Orig. 19.3
Adr. DQ 14.1
Connec. 23
Syb.Ad. EY-HTF-02-W
1OQ2
Heater_2
X1
105
0.5
S | Ö
9.2
power heater 3
Comp. 11A1
Orig. 19.3
Adr. DQ 14.2
Connec. 24
Syb.Ad. EY-HTF-03-W
1OQ3
Heater_3
X1
106
0.5
S | Ö
9.3
power heater 4
Comp. 11A1
Orig. 19.3
Adr. DQ 14.3
Connec. 25
Syb.Ad. EY-HTF-04-W
1OQ4
Heater_4
X1
106
0.5
S | Ö
9.4
power heater 5
Comp. 11A1
Orig. 19.3
Adr. DQ 14.4
Connec. 26
Syb.Ad. EY-HTF-05-W
1OQ5
Heater_5
X1
107
0.5
S | Ö
9.5
power heater 6
Comp. 11A1
Orig. 19.3
Adr. DQ 14.5
Connec. 27
Syb.Ad. EY-HTF-06-W
1OQ6
Heater_6
X1
107
0.5
S | Ö
9.6
GND_24V
7.0
GND_24V
13.4
Proprietary notice after DIN ISO 16016 attend!
previous Page: 9
state
variation
date
name
project
Process.
crea.date
15.03.2016
name
Haydn
prof.
Norm
Costumer
DLR
Project description
REPA
Page Description
SPS Output Heater
next Page: 11
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Location
Drawing.-Nr.:
Facility:
Place
Page: 10
by 24


L1_Sockets
L2_Sockets
L3_Sockets
N
22.7
PE
12.0
X1
7F4
RCD 3~/40A
7F5
B16/3
Socket
7X3
7F1 Protection Socket
B16
Socket
7X2
1.8
1.8
1.8
9.9
7.9
Proprietary notice after DIN ISO 16016 attend!
previous Page: 10
next Page: 12
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Location
Drawing.-Nr.:
Facility:
Place
Page: 11
by 24
Page Description
Sockets
Project description
REPA
Costumer
DLR
state
variation
date
name
project
Process.
prof.
Norm
creа.date
01.03.2016
name
Haydn

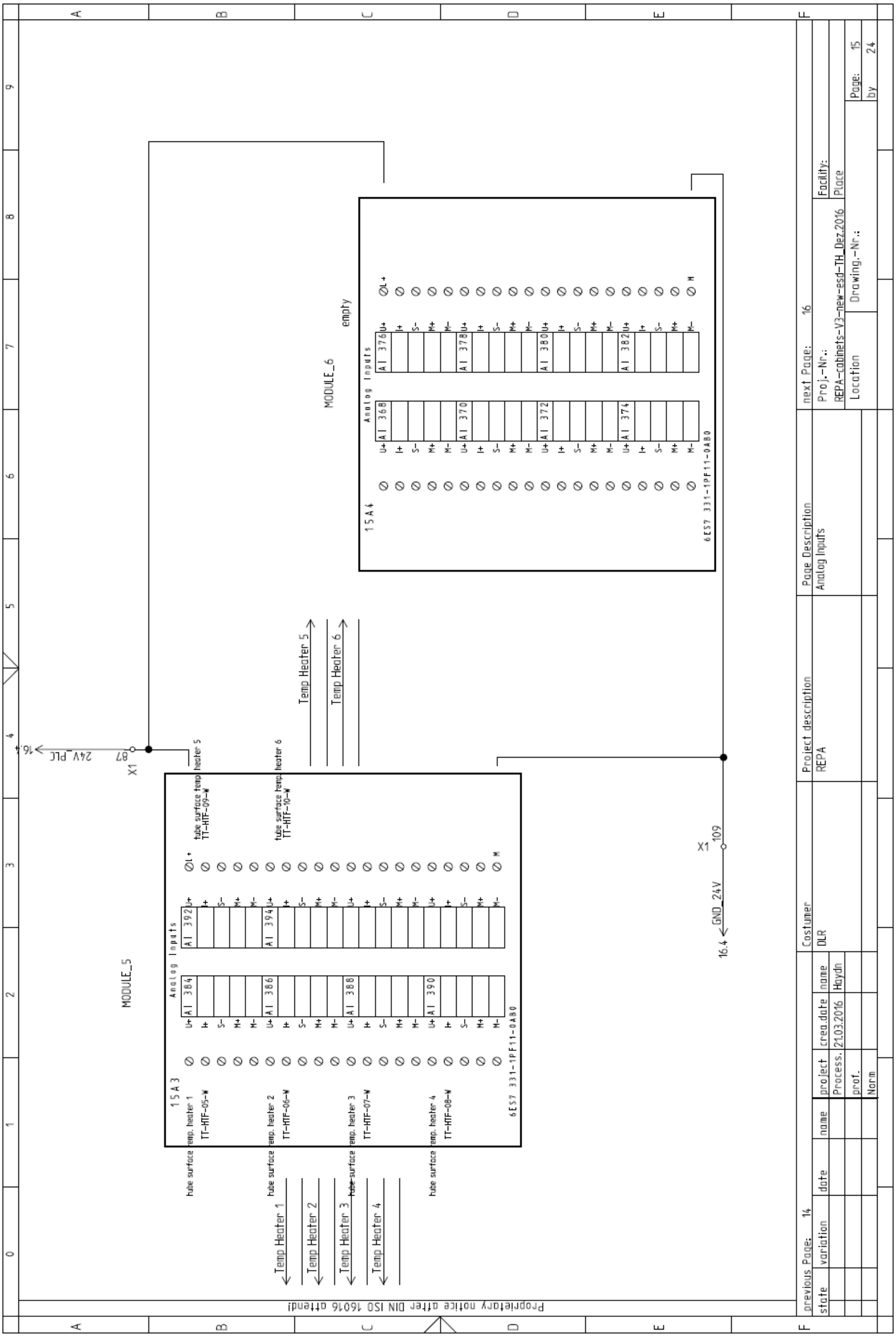

L1_UPS
N_UPS
PLC Power Supply
GND_PLC Power Supply
GND_230V
12F10
6A
X1
8F3
230V_Control
24V
Syb.Ad. ES-HTF-01-W
Connec. 23
Adr. DI 6.1
Orig. 17.5
Comp. 10A1
protetion 230 V contol (8F3)
12F11
12E1
light
panel PC
12F12
10A
8F2
Socket UPS
8X1
PE
next Page: 13
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Location
Facility:
Place
Drawing.-Nr.:
Page: 12
by 24
Page Description
UPS
Project description
REPA
Costumer
DLR
name
Haydn
crea.date
02.03.2016
project
Process.
prof.
Norm
previous Page: 11
state
variation
date
Proprietary notice after DIN ISO 16016 attend!


13A2
PS307
Power Supply 24V
DC24V
VOLTAGE SELECTOR
ON
OFF
12A1
13SM2
Selectivity Modul
13SM2
Current values:
1: 3 A
4: 10 A
12SM1
Selectivity Modul
12SM1
Curret values:
4: 5 A
GND_24V
X2 control supply servo contro
Supply CPU PLC
24V_PLC
GND_PLC Power Supply
PLC Power Supply
24 V_emegency-stop
Sensor 24V
SPS
PE
reset selectivity modul 2
Proprietary notice after DIN ISO 16016 attend!
previous Page: 12
next Page: 14
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Drawing.-Nr.:
Location
Facility:
Place
Page: 13
by 24
Page Description
UPS 2
Project description
REPA
Costumer
DLR
crea.date 14.03.2016
name Haydn


Temp. multi force 2.1
M2.1
Temp. multi force 2.2
M2.2
3 dummy sensors have to be mounted
only 1 multiforce sensor is available 07.04.2016
14A3
TT-HTF-13-W temperature multi force 2.1
TT-HTF-14-W temperature multi force 2.2
Analog Input 20
6ES7 331-7PF01-0AB0
Bearing Pump1
Bearing Pump2
Bearing Pump3
Bearing Pump4
Lubrication Oil HTF Pump1
Lubrication Oil HTF Pump2
Lubrication Oil HTF Pump3
Lubrication Oil HTF Pump4
Temp. multi force1.1
M1.1
Temp. multi force 1.2
M1.2
MODULE_9
14A2
TT-HTF-02-W Bearing, HTF pump
TT-HTF-03-W lubricating oil, HTF pump
TT-HTF-11-W temperature multi force 1.1
TT-HTF-12-W temperature multi force 1.2
24V_PLC
IM360/361
X1 OUT
14A4
IM 360
9A1
SIEMENS
Memory Card
RUN-P
RUN
STOP
RESET
X1 MPI
X2 DP
Supply CPU PL
GND_24V
Proprietary notice after DIN ISO 16016 attend!
Costumer
DLR
Project description
REPA
Page Description
PLC and AI
next Page: 15
previous Page: 13
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Location
Facility:
Place
Drawing.-Nr.:
Page: 14
by 24
crea.date
04.03.2016
name
Haydn
project
Process.
prof.
Norm
state
variation
date
name

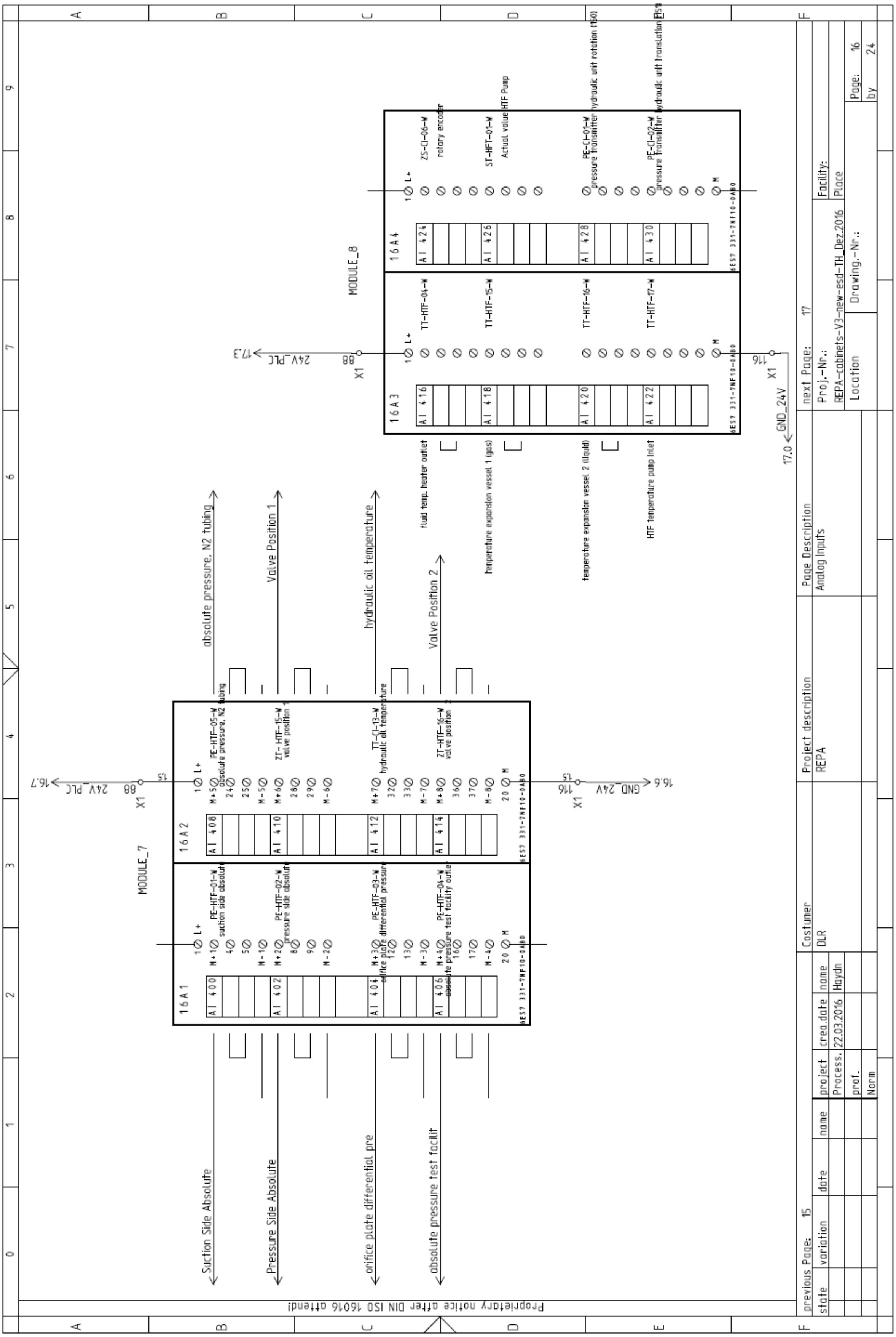
hochschule mannheim

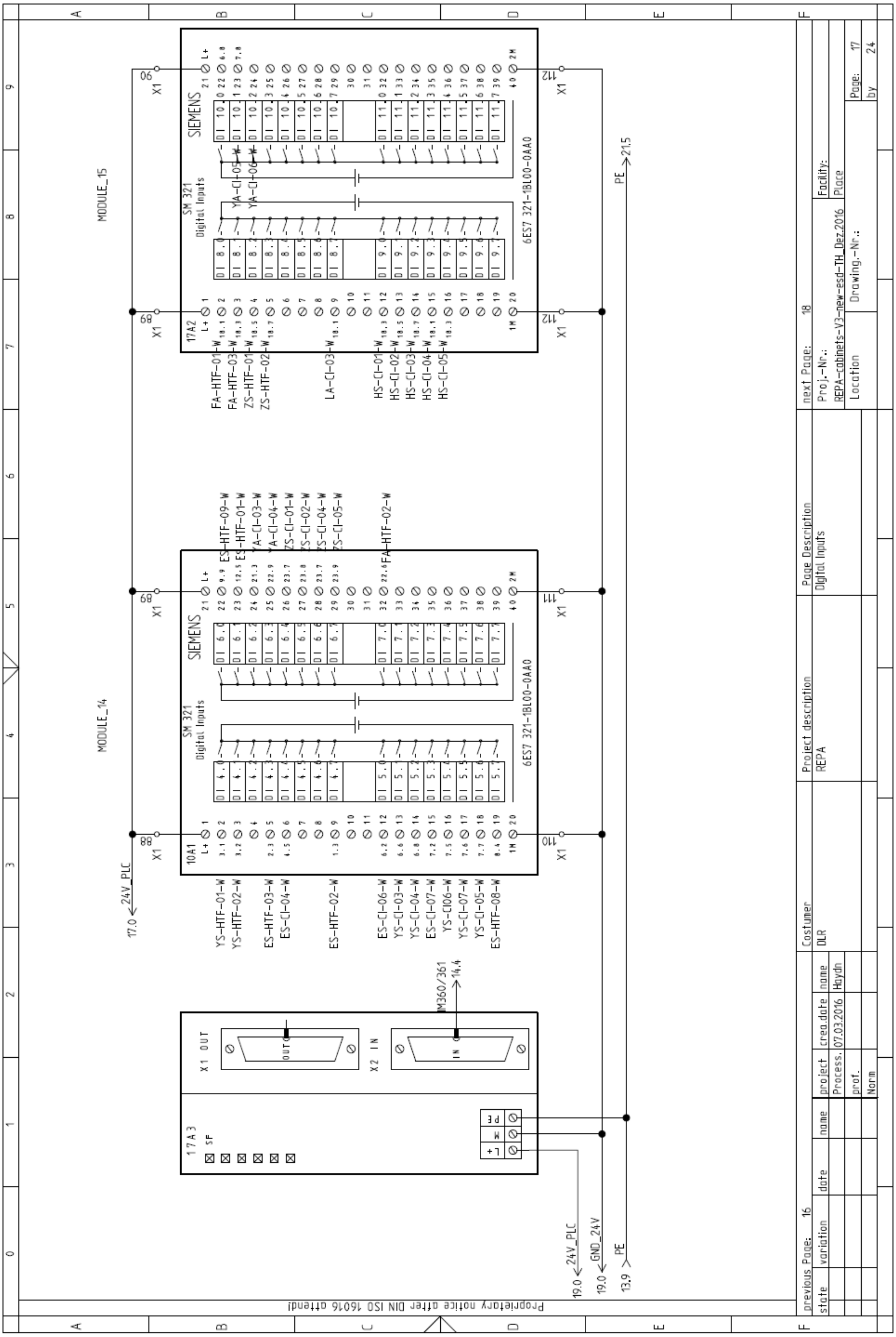
DLR

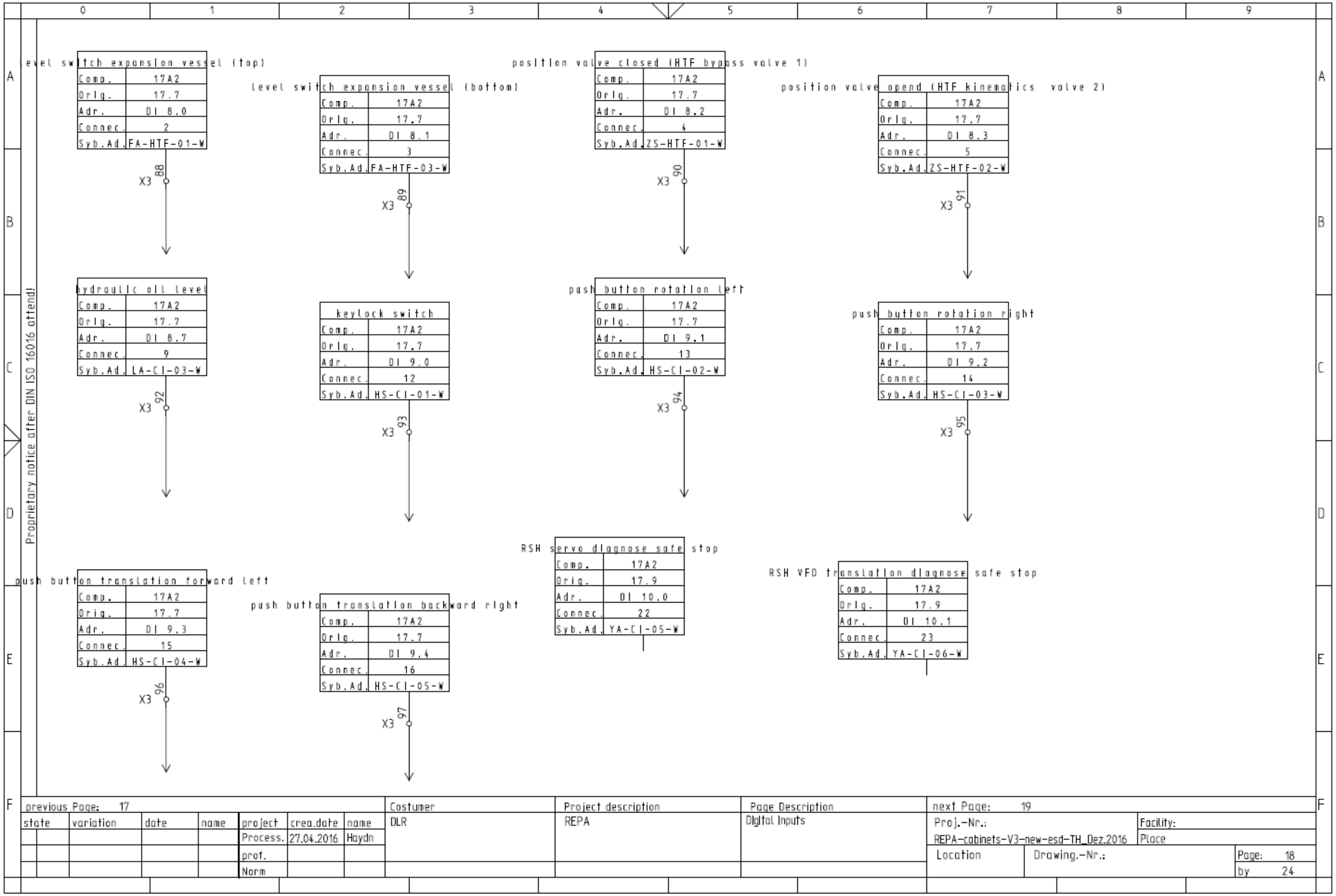


hochschule mannheim

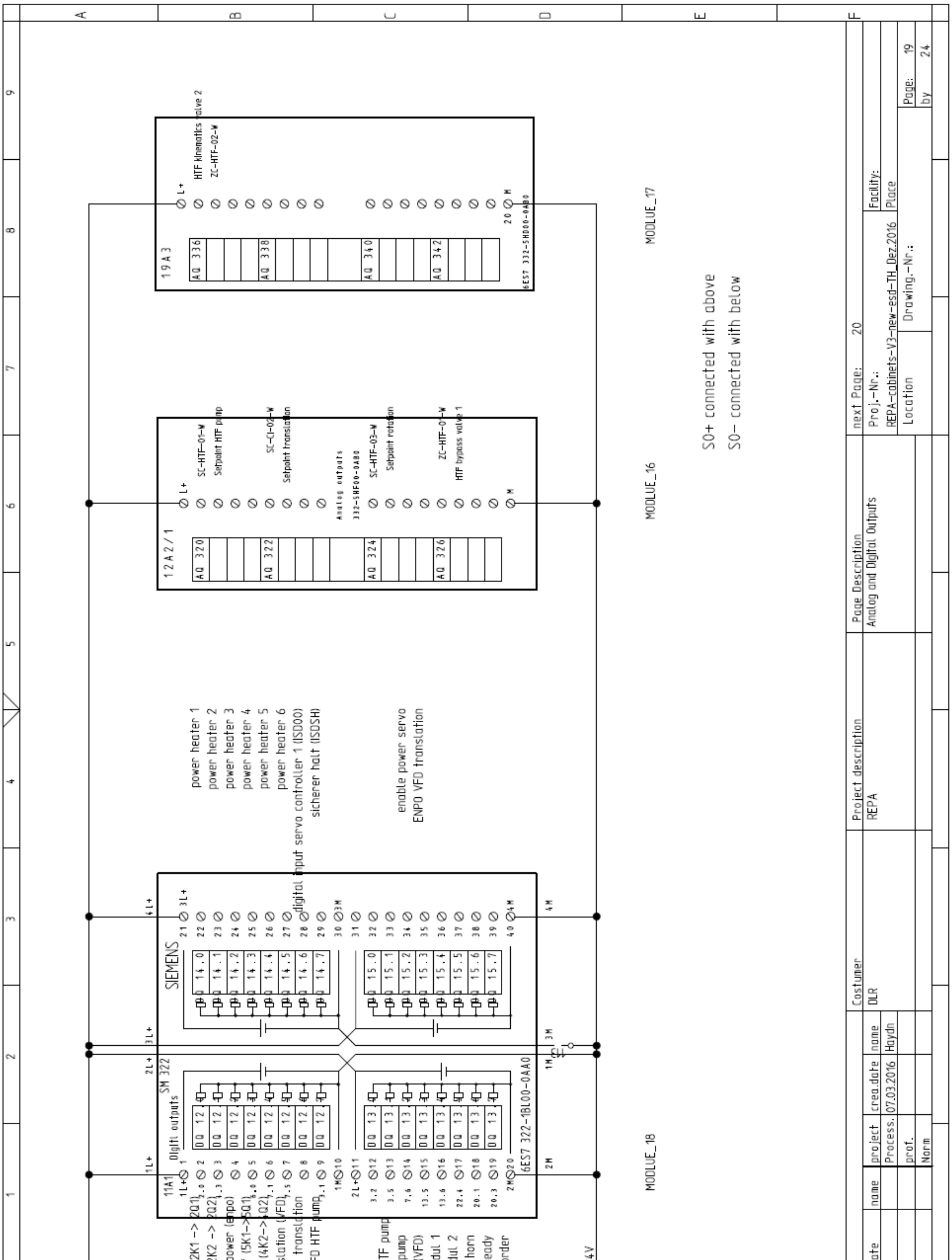
DLR

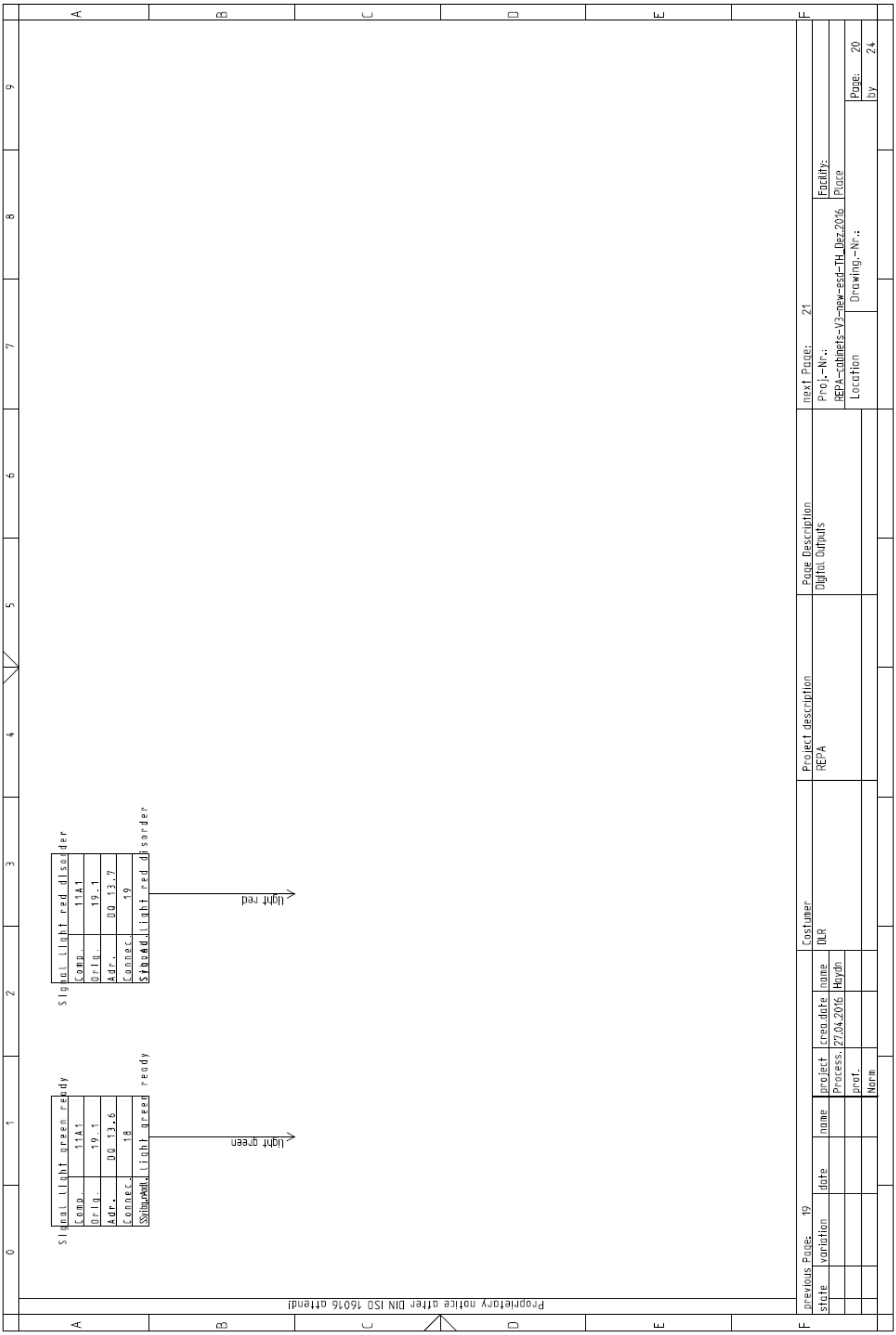


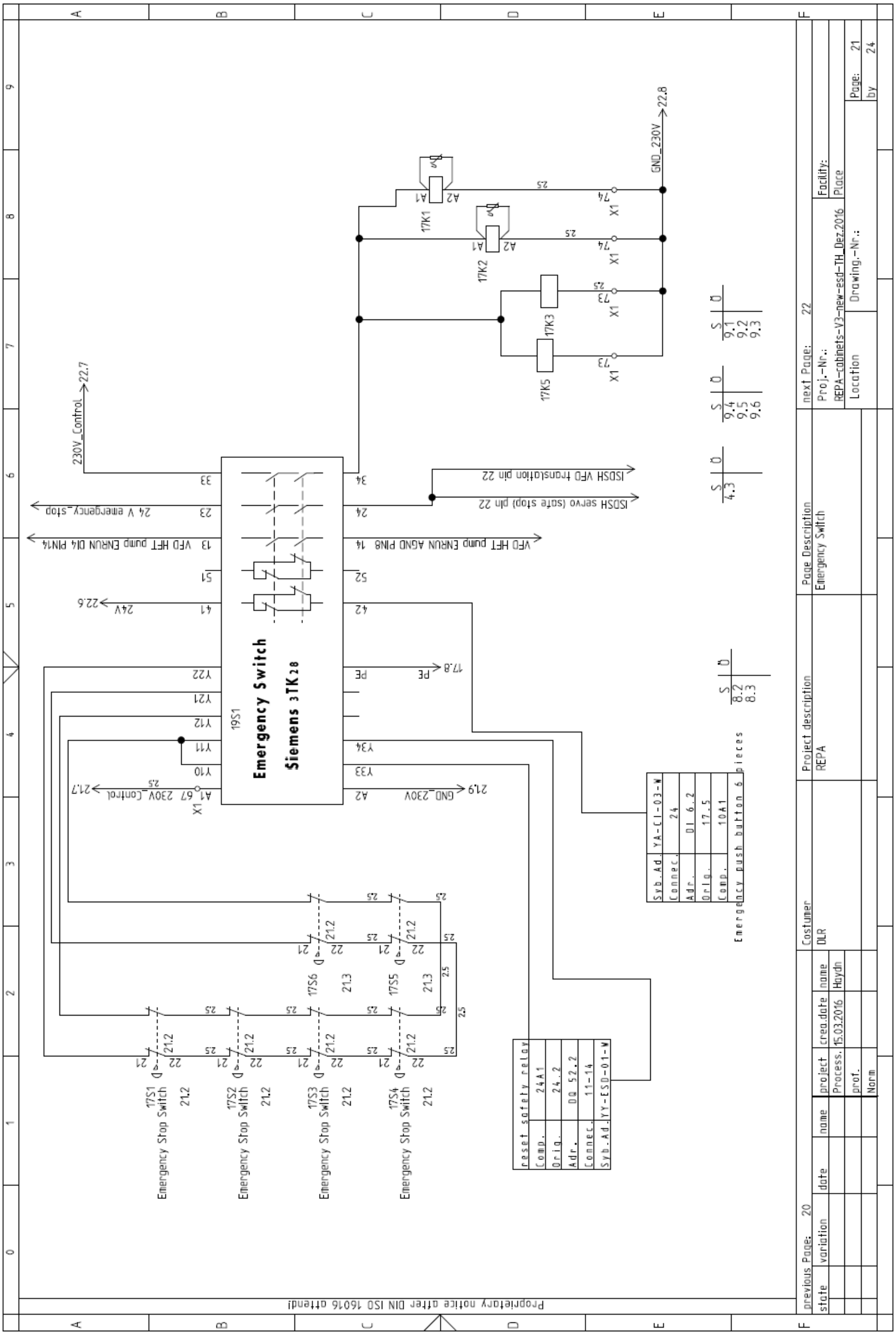

MODULE_15
MODULE_14
SIEMENS
SM 321
Digital Inputs
6ES7 321-1BL00-0AA0
17A2
10A1
17A3
X1 OUT
X2 IN
24V_PLC
GND_24V
PE
Proprietary notice after DIN ISO 16016 attend!
Page Description
Digital Inputs
Project description
REPA
Costumer
DLR
REPA-cabinets-V3-new-esd-TH_Dez.2016
crea.date 07.03.2016
name Haydn



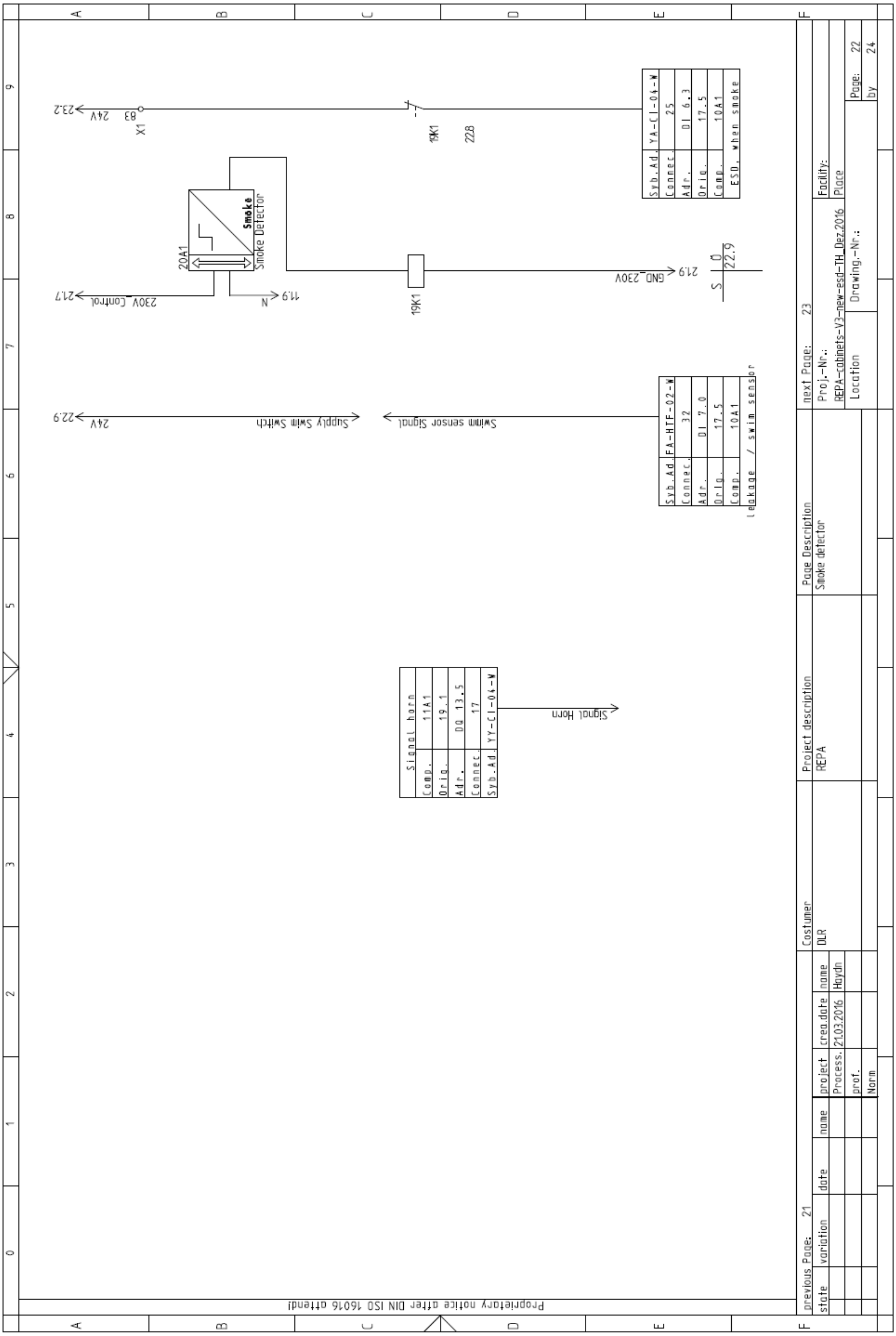
level switch expansion vessel (top)
Comp. 17A2
Orig. 17.7
Adr. DI 8.0
Connec. 2
Syb.Ad. FA-HTF-01-W
X3 88
level switch expansion vessel (bottom)
Comp. 17A2
Orig. 17.7
Adr. DI 8.1
Connec. 3
Syb.Ad. FA-HTF-03-W
X3 89
position valve closed (HTF bypass valve 1)
Comp. 17A2
Orig. 17.7
Adr. DI 8.2
Connec. 4
Syb.Ad. ZS-HTF-01-W
X3 90
position valve opend (HTF kinematics valve 2)
Comp. 17A2
Orig. 17.7
Adr. DI 8.3
Connec. 5
Syb.Ad. ZS-HTF-02-W
X3 91
hydraulic oil level
Comp. 17A2
Orig. 17.7
Adr. DI 8.7
Connec. 9
Syb.Ad. LA-CI-03-W
X3 92
keylock switch
Comp. 17A2
Orig. 17.7
Adr. DI 9.0
Connec. 12
Syb.Ad. HS-CI-01-W
X3 93
push button rotation left
Comp. 17A2
Orig. 17.7
Adr. DI 9.1
Connec. 13
Syb.Ad. HS-CI-02-W
X3 94
push button rotation right
Comp. 17A2
Orig. 17.7
Adr. DI 9.2
Connec. 14
Syb.Ad. HS-CI-03-W
X3 95
RSH servo diagnose safe stop
Comp. 17A2
Orig. 17.9
Adr. DI 10.0
Connec. 22
Syb.Ad. YA-CI-05-W
RSH VFD translation diagnose safe stop
Comp. 17A2
Orig. 17.9
Adr. DI 10.1
Connec. 23
Syb.Ad. YA-CI-06-W
push button translation forward left
Comp. 17A2
Orig. 17.7
Adr. DI 9.3
Connec. 15
Syb.Ad HS-CI-04-W
X3 96
push button translation backward right
Comp. 17A2
Orig. 17.7
Adr. DI 9.4
Connec. 16
Syb.Ad. HS-CI-05-W
X3 97
Proprietary notice after DIN ISO 16016 attend!
previous Page: 17
state
variation
date
name
project
crea.date
name
Process.
27.04.2016
Haydn
prof.
Norm
Costumer
DLR
Project description
REPA
Page Description
Digital Inputs
next Page: 19
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Facility:
Place
Location
Drawing.-Nr.:
Page: 18
by 24

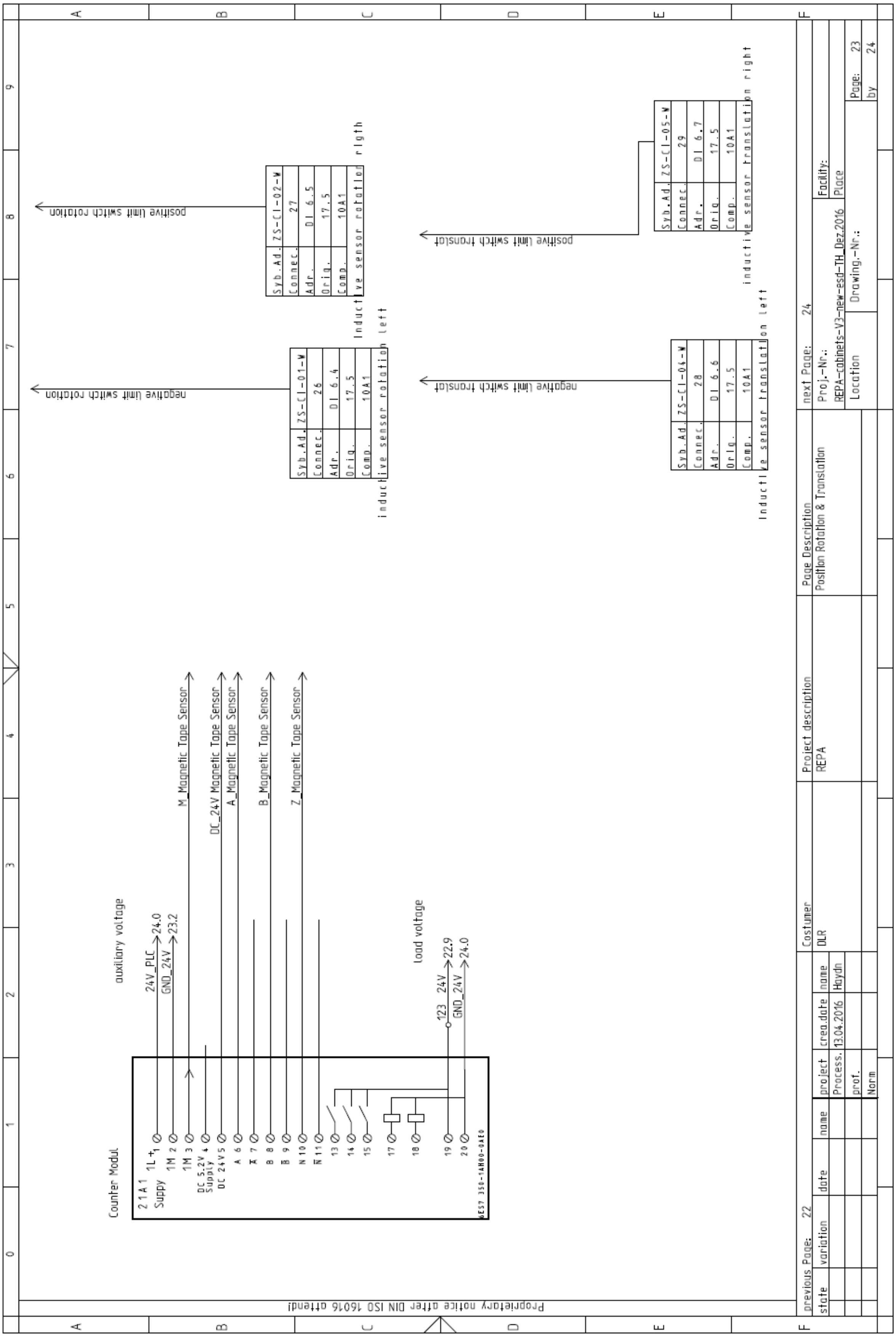

23.2 24V_PLC
23.2 GND_24V
11A1
Digitl outputs
SM 322
SIEMENS
6ES7 322-1BL00-0AA0
HTF pump on/off (2K1 -> 2Q1)
hyd oil cooler pump on/off (2K2 -> 2Q2)
enable power (enpo)
rotation on/off (5K1->5Q1)
translation on/off (4K2->4Q2)
start translation (VFD)
Power enable VFD translation
Start/Stop VFD HTF pump
CW/CCW (reset?)VFD HTF pump
S4 (ramp pair) VFD HTF pump
CW/CCW translation (VFD)
reset selectivity modul 1
reset selectivity modul 2
Signal horn
Signal light green ready
Signal light red disorder
power heater 1
power heater 2
power heater 3
power heater 4
power heater 5
power heater 6
digital input servo controller 1 (ISDOO)
sicherer halt (ISDSH)
enable power servo
ENPO VFD translation
12A2/1
AQ 320
AQ 322
AQ 324
AQ 326
SC-HTF-01-W
Setpoint HTF pump
SC-CI-02-W
Setpoint translation
Analog outputs
332-5HF00-0AB0
SC-HTF-03-W
Setpoint rotation
ZC-HTF-01-W
HTF bypass valve 1
19A3
AQ 336
AQ 338
AQ 340
AQ 342
HTF kinematics valve 2
ZC-HTF-02-W
6ES7 332-5HD00-0AB0
MODLUE_18
MODLUE_16
MODLUE_17
S0+ connected with above
S0- connected with below
Proprietary notice after DIN ISO 16016 attend!
previous Page: 18
state
variation
date
name
project
crea.date
name
Process.
07.03.2016
Haydn
prof.
Norm
Costumer
DLR
Project description
REPA
Page Description
Analog and Digital Outputs
next Page: 20
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Facility:
Place
Location
Drawing.-Nr.:
Page: 19
by 24

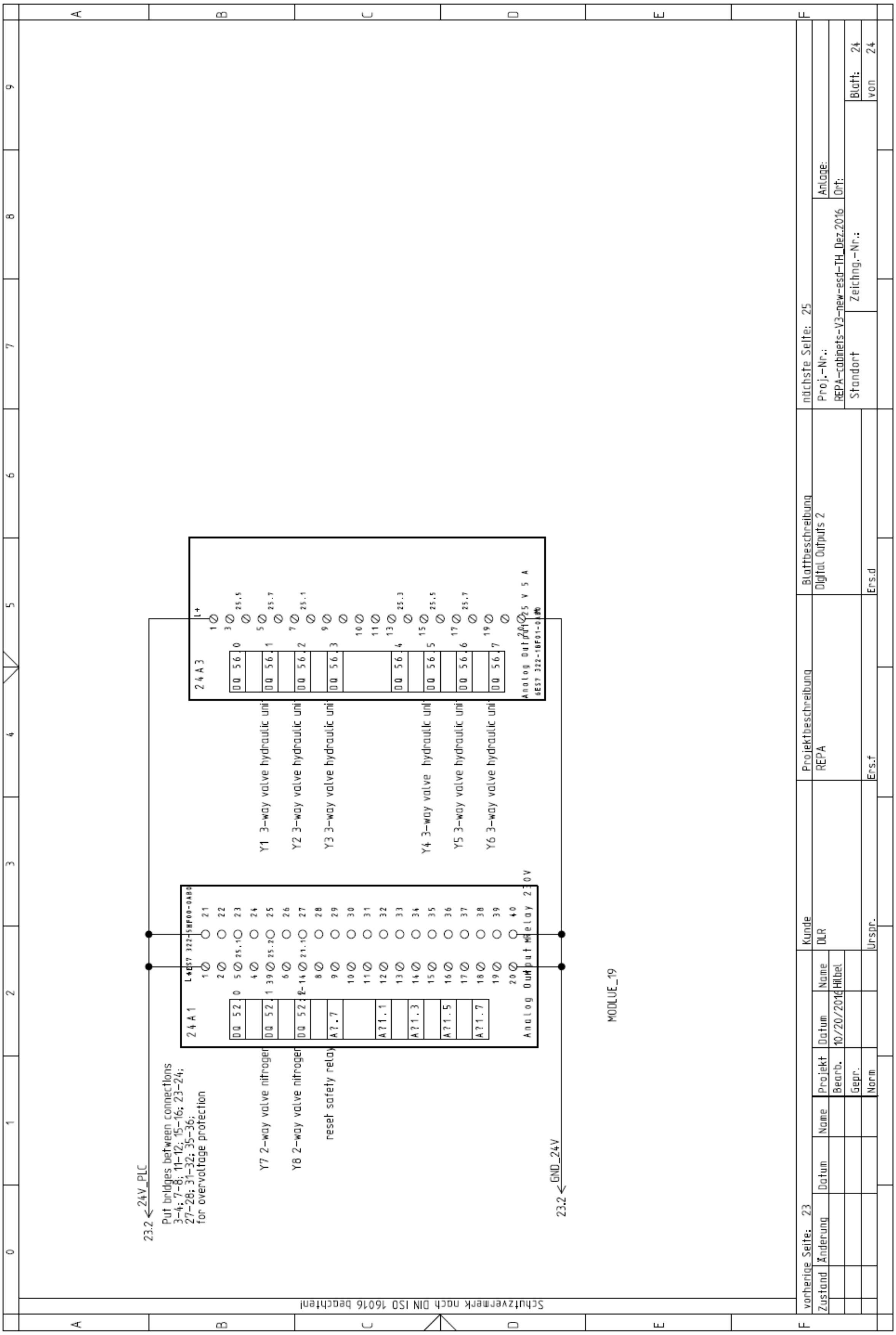

Signal light green ready
Comp. 11A1
Orig. 19.1
Adr. DQ 13.6
Connec. 18
Light green ready
Light green
Signal light red disorder
Comp. 11A1
Orig. 19.1
Adr. DQ 13.7
Connec. 19
Light red disorder
Light red
Proprietary notice after DIN ISO 16016 attend!
previous Page: 19
state
variation
date
name
project
Process.
prof.
Norm
crea.date 27.04.2016
name Haydn
Costumer
DLR
Project description
REPA
Page Description
Digital Outputs
next Page: 21
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
Location
Drawing.-Nr.:
Facility:
Place
Page: 20
by 24

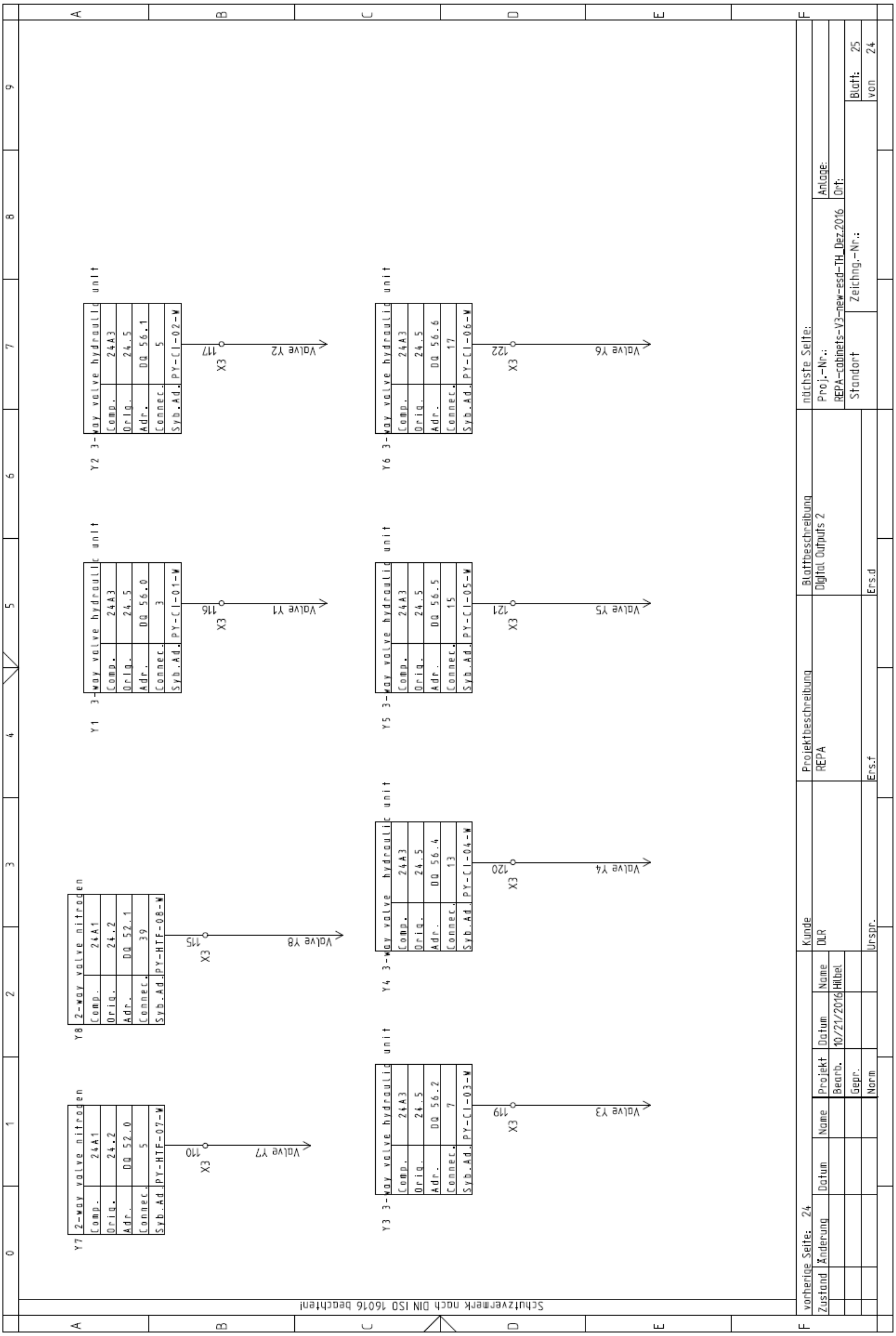

Emergency Switch
Siemens 3TK28
19S1
17K1
17K2
17K3
17K5
17S1 Emergency Stop Switch
17S2 Emergency Stop Switch
17S3 Emergency Stop Switch
17S4 Emergency Stop Switch
17S5
17S6
230V_Control
GND_230V
24 V emergency_stop
VFD HFT pump ENRUN DI4 PIN14
VFD HFT pump ENRUN AGND PIN8
ISDSH VFD translation pin 22
ISDSH servo (safe stop) pin 22
Emergency push button 6 pieces
reset safety relay
Proprietary notice after DIN ISO 16016 attend!
previous Page: 20
next Page: 22
Page: 21
by 24
Page Description
Emergency Switch
Project description
REPA
Costumer
DLR
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
crea.date 15.03.2016
name Haydn
Facility:
Place
Location
Drawing.-Nr.:

hochschule mannheim




Counter Modul
auxiliary voltage
24V_PLC 24.0
GND_24V 23.2
load voltage
24V 22.9
GND_24V 24.0
M_Magnetic Tape Sensor
DC_24V Magnetic Tape Sensor
A_Magnetic Tape Sensor
B_Magnetic Tape Sensor
Z_Magnetic Tape Sensor
negative limit switch rotation
positive limit switch rotation
negative limit switch translat
positive limit switch translat
inductive sensor rotation left
Inductive sensor rotation rigth
Inductive sensor translation left
inductive sensor translation right
Syb.Ad. ZS-CI-01-W
Syb.Ad. ZS-CI-02-W
Syb.Ad. ZS-CI-04-W
Syb.Ad. ZS-CI-05-W
Page Description
Position Rotation & Translation
Project description
REPA
Costumer
DLR
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
next Page: 24
previous Page: 22
Page: 23
by 24
crea.date 13.04.2016
name Haydn
Proprietary notice after DIN ISO 16016 attend!


Blattbeschreibung
Digital Outputs 2
Projektbeschreibung
REPA
Kunde
DLR
Proj.-Nr.:
REPA-cabinets-V3-new-esd-TH_Dez.2016
nächste Seite: 25
vorherige Seite: 23
Blatt: 24
von 24
Bearb. 10/20/2016 Hilbel
Put bridges between connections 3-4; 7-8; 11-12; 15-16; 23-24; 27-28; 31-32; 35-36; for overvoltage protection
24V_PLC
GND_24V
MODULE_19
Y1 3-way valve hydraulic unit
Y2 3-way valve hydraulic unit
Y3 3-way valve hydraulic unit
Y4 3-way valve hydraulic unit
Y5 3-way valve hydraulic unit
Y6 3-way valve hydraulic unit
Y7 2-way valve nitrogen
Y8 2-way valve nitrogen
reset safety relay
24A1
24A3
Schutzvermerk nach DIN ISO 16016 beachten!


Y7 2-way valve nitrogen
Comp. 24A1
Orig. 24.2
Adr. DQ 52.0
Connec. 5
Syb.Ad. PY-HTF-07-W
X3 110
Valve Y7
Y8 2-way valve nitrogen
Comp. 24A1
Orig. 24.2
Adr. DQ 52.1
Connec. 39
Syb.Ad. PY-HTF-08-W
X3 115
Valve Y8
Y1 3-way valve hydraulic unit
Comp. 24A3
Orig. 24.5
Adr. DQ 56.0
Connec. 3
Syb.Ad. PY-CI-01-W
X3 116
Valve Y1
Y2 3-way valve hydraulic unit
Comp. 24A3
Orig. 24.5
Adr. DQ 56.1
Connec. 5
Syb.Ad. PY-CI-02-W
X3 117
Valve Y2
Y3 3-way valve hydraulic unit
Comp. 24A3
Orig. 24.5
Adr. DQ 56.2
Connec. 7
Syb.Ad. PY-CI-03-W
X3 119
Valve Y3
Y4 3-way valve hydraulic unit
Comp. 24A3
Orig. 24.5
Adr. DQ 56.4
Connec. 13
Syb.Ad. PY-CI-04-W
X3 120
Valve Y4
Y5 3-way valve hydraulic unit
Comp. 24A3
Orig. 24.5
Adr. DQ 56.5
Connec. 15
Syb.Ad. PY-CI-05-W
X3 121
Valve Y5
Y6 3-way valve hydraulic unit
Comp. 24A3
Orig. 24.5
Adr. DQ 56.6
Connec. 17
Syb.Ad. PY-CI-06-W
X3 122
Valve Y6
Schutzvermerk nach DIN ISO 16016 beachten!
vorherige Seite: 24
Zustand Änderung Datum Name
Projekt Datum Name
Bearb. 10/21/2016 Hilbel
Gepr.
Norm
Kunde DLR
Urspr.
Projektbeschreibung REPA
Ers.f
Blattbeschreibung Digital Outputs 2
Ers.d
nächste Seite:
Proj.-Nr.: REPA-cabinets-V3-new-esd-TH_Dez.2016
Standort
Zeichng.-Nr.:
Anlage:
Ort:
Blatt: 25
von 24