Master Thesis

CONCEPTION OF AN AUTOMATIZED BROILER BREEDER MANAGEMENT BUILDING

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Automation Technology - Economy

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Graz, December 2016

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Signature

DECLARATION OF ACADEMIC HONESTY

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

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I would like to express my sincere gratitude to my thesis advisor Dipl.-Ing. Dr. techn. Manfred Pauritsch for the supervision of my thesis. My sincere thanks also goes to the agricultural holding Taucher for the support and help to finish this project.

ABSTRACT

The broiler breeder management farm Taucher manages three big poultry houses. These buildings accommodate chickens and roosters under the same roof. Instead of selling the eggs to the consumer, Taucher sells the fertilized eggs to another company, where the eggs are hatched with the help of artificial breeders. These eggs are of higher value than the non-fertilized eggs and are therefore more profitable. The result of this process are chicks, which are used as fattened chickens later.

Each poultry house from the agricultural holding is accessed by a central control system, which is responsible for the living and environmental conditions of the poultry animals in the henhouses. Mr. Josef Taucher, the owner of the farm, built another henhouse that is newer and bigger than the old ones. As he was not satisfied with his existing management system for the old henhouses, he was in demand of a newer, better control system. The main reason for that is that the old system is very complex, not very user friendly and has limited adjustment options. Therefore, it is not possible to create optimal living conditions for the poultry animals in his existing henhouse and the profit cannot be maximized.

The goal of this thesis was to develop a concept of an automated broiler breeder management building and to implement this concept in the new henhouse. This control system is responsible for the climate, feeding, lighting, egg-collection and water control system. Moreover, the new developed control system will improve the egg laying performance, which generates a higher profit for the farmer.

The result of this work is a better working control system for the broiler breeder building. It is easier to understand, yet it offers a more powerful interface for the farmer. The customized design of the user interface was developed together with the operator and enables a high usability and a comfortable handling of the system.

KURZFASSUNG

Der Masthuhn Elterntierhaltung Betrieb Taucher betreibt drei Hühnerställe mit Hühnern und Hähnen, wobei diese gemischt in den Gebäuden gehalten werden. Anstatt die Eier weiterzuverkaufen, verkauft Taucher die befruchteten Eier von den Hühnern an ein anderes Unternehmen, welches die Aufgabe hat, diese Eier auszubrüten. Das Ergebnis dieses Prozesses sind Küken, welche später als Brathähnchen verwendet werden.

Jeder Hühnerstall vom landwirtschaftlichen Betrieb Taucher wird von einer zentralen Steuereinheit, welche für die Lebens- und Umgebungsbedingungen der Geflügeltiere im Hühnerstall verantwortlich ist, gesteuert. Herr Josef Taucher, der Besitzer des landwirtschaftlichen Betriebes, ließ einen neuen und größeren Hühnerstall bauen. Da er mit den alten Steuerungssystemen nicht zufrieden war, benötigt er ein neueres, besseres System. Der Hauptgrund für das ist die Tatsache, dass die Benutzeroberfläche zu komplex ist und die Einstellungsmöglichkeiten sehr beschränkt sind. Deswegen ist es nicht möglich, optimale Lebensbedingungen für die Geflügeltiere zu schaffen und der Profit kann nicht maximiert werden.

Das Ziel dieser Arbeit war es, ein Konzept für eine Steuerung für einen Masthuhn Elterntier Stall zu entwickeln und dieses Konzept dementsprechend im neuen Gebäude umzusetzen. Diese Steuerung ist für Klima-, Fütterungs-, Licht-, Wasserversorgungs- und das Eiersammelsystem verantwortlich. Des Weiteren soll das neu entwickelte Steuerungssystem die Legeleistung der Hühner fördern, was dem Betrieb Taucher einen höheren Profit bringt.

Das Ergebnis dieses Projektes ist ein sehr gut arbeitendes Steuerungssystem für das Masthuhn Elterntierhaltungsgebäude welches eine gut verständliche und mächtige Benutzeroberfläche hat. Die individuell designte Benutzeroberfläche wurde in Zusammenarbeit mit dem Benutzer erstellt und ermöglicht eine einfache Bedienung des Systems.

TABLE OF CONTANTS

1 INTRODUCTION

1.1 Initial situation

The broiler breeder management farm, TAUCHER, manages three big poultry houses with around 11,000 chickens and 1,100 roosters. Most of these eggs from the hens are fertilized and the chickens and roosters are kept together in the henhouses. Taucher sells their fertilized eggs, which are also called hatching eggs, to another company, which has the assignment to breed these eggs with artificial breeders. The result of this process are chicks, which are used as fattened chickens later. In the end of the year 2015, the agricultural holding Taucher started building a newer and bigger poultry house, because they want to expand their business and sell more fertilized eggs. Fig. 1 shows the poultry farm Taucher on the left picture with the new henhouse in the front of the farm. This newer, bigger building with the number four is called ST4 and offers enough place for 7500 poultry animals.

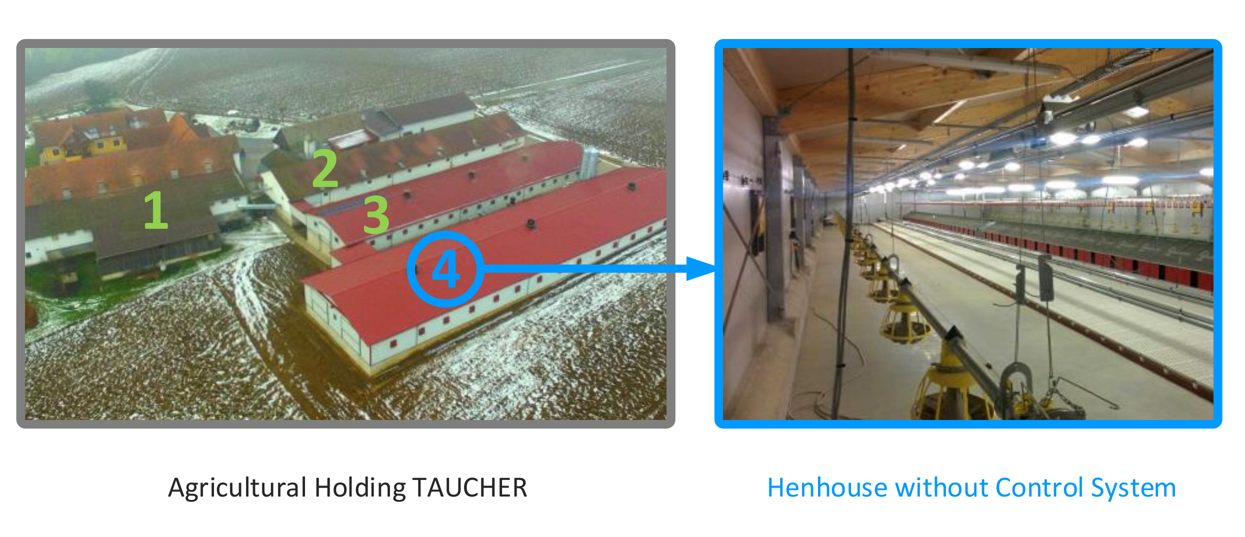


Fig. 1: Initial situation agricultural holding Taucher, Source: Own illustration

Each poultry house is accessed by a central control unit (CPU), which is responsible for the environmental conditions and the egg collection systems in these buildings. Many things have to be considered to meet these conditions. Henhouse ST1, ST2 and ST3 are in operation and they already have control systems, which have been working since a couple of years. The right side of Fig. 1 displays the initial situation of the henhouse from the inside. The new building ST4 is without chickens and has no control system yet. An Austrian company named JANKER, which produces components for chicken farmers, installed all the necessary hardware equipment for the henhouse ST4, but detailed information will be explained later in chapter 3. All motors and lights are already installed, but there is no central processing unit that accesses all these components. For instance, all the lights in the poultry house are only controlled by one switch and it is only possible to switch all lights on or off. The agricultural holding Taucher needs an automized broiler breeder management system, which controls the complete henhouse.

1.2 Problem definition

Fig. 2 represents the already existing control system for henhouse 3. The farmer and user of this broiler breeder management system has limited adjustment options and is not able to create optimal living conditions for the chickens and roosters. The screen of the user interface is small and does not show a lot of measured values and it is difficult and time-consuming to change setting values. Furthermore, replacement components are very expensive and you need a special educated engineer from the manufacturing company to adjust the software. It is not very easy to expand the system, because the control boxes are not very powerful and it is highly likely you will need a new box, when you want to add new components.

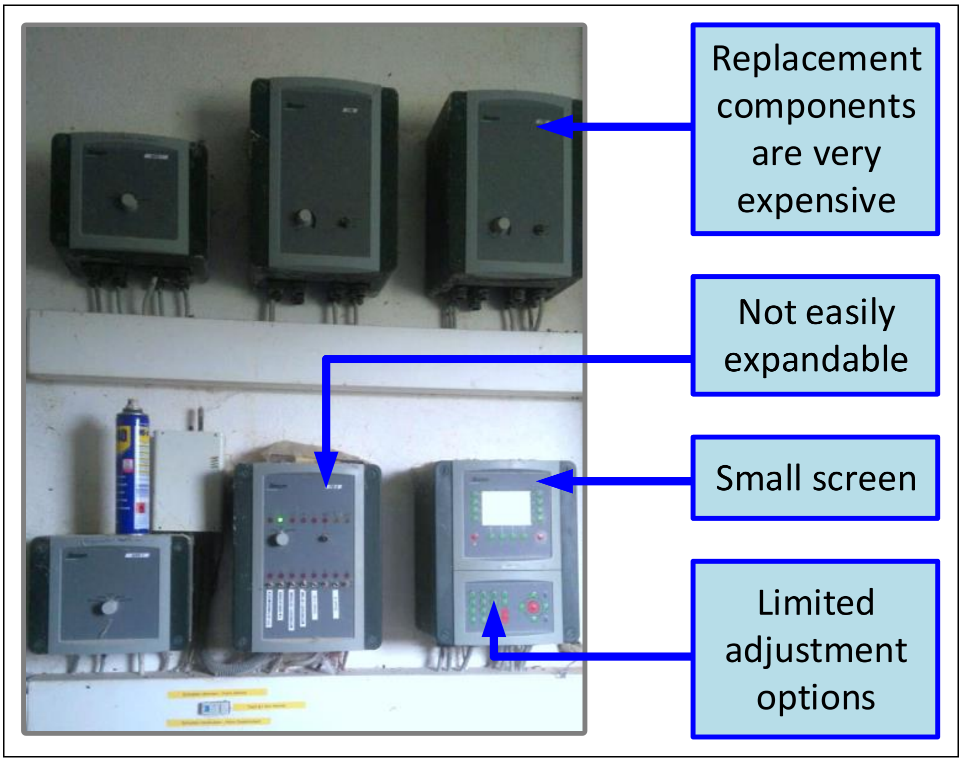


Fig. 2: Control system for henhouse 3, Source: Own illustration

There are several companies which produce products for poultry farmers and also offer a control system with a graphical user interface, but the problem is these software solutions are very expensive and not individually fitted to the farmer's wishes. Mr. Josef Taucher, the main contact person and leader of the agricultural holding Taucher, is unsatisfied with the existing user interface of the control system for his henhouses. Taucher wants to have a cheaper and more individual solution for the new poultry house.

1.3 Research Objectives

The goal of this master thesis is to develop a concept of an automatized broiler breeder management building and to implement this concept accordingly. This control system is responsible for climate adjustments, the amount of food and water the chickens get, the egg collection and the lighting system. Industrial sensors and actuators are used for the control system. The overarching scientific question is "How can a concept of a broiler breeder management system to improve the egg laying performance of the chickens be created?"

2 AUTOMATIZED BROILER BREEDER MANAGEMENT BUILDING

2.1 Broiler breeder management system

An automatized broiler breeder management building (Fig. 3) is an agricultural building with hens and roosters where a central processing unit controls all electrically controllable components to generate optimal living conditions for the animals and to collect their eggs. As opposed to eggs from layers, hatching eggs in a broiler breeder farm are not meant for human consumption. It is crucial that the system is well designed, because it is possible to control and improve the laying performance of the chickens, which helps the farmer to earn more money.[1] The automatized broiler breeder management system has five sub control systems:

- Climate control system
- Feeding control system
- Light control system
- Egg collecting System
- Water control system

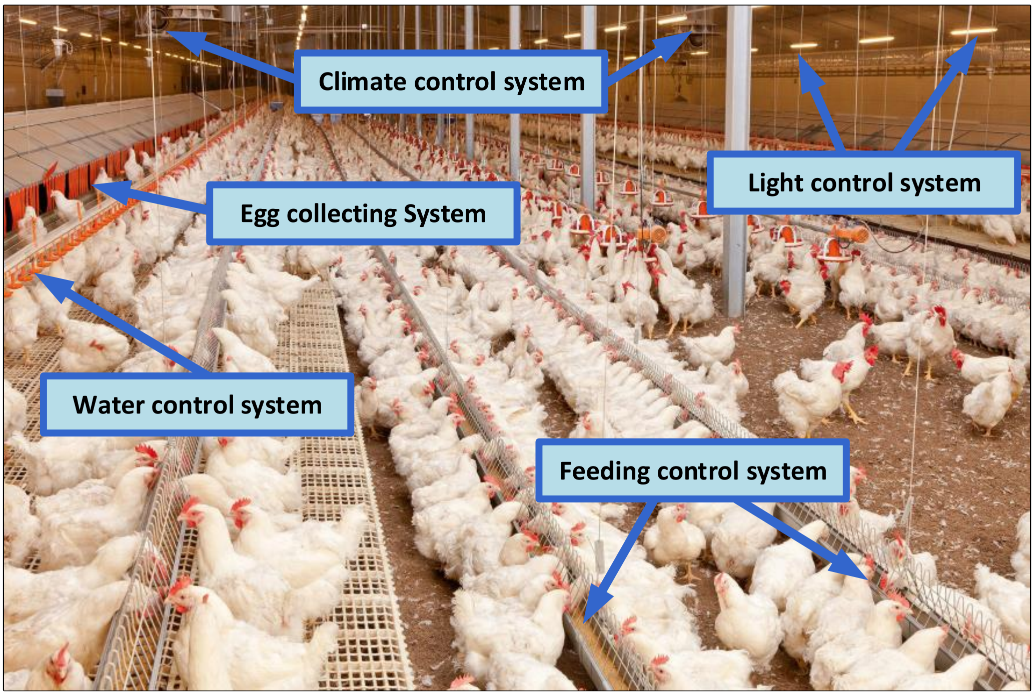


Fig. 3: Broiler Breeder Management Building, Source: Lilian Industry (2016), Online-Source [13.11.2016] (modified).

In order to provide the animals with fresh air, water, food and light, it is very important that all five systems work together perfectly and provide a certain amount of robustness. Also, the egg collection system is responsible for collecting all the eggs.[2]

[1] Cf. Arbor Acres (Ed.) (2011), pp. 36-37.

[2] Cf. Leeson/Summer (2009), pp. 23-24.

2.2 Types of henhouses

There are a lot of different types of henhouses and they are mainly distinguished by the amount of hens and the type of animals which are housed in the building. Basically, chicken farmers discern between three types of chickens:

- Broilers, which are used for meat production
- Layers, which are used for edible eggs
- Broiler breeder hens, which produce fertilized eggs

Broilers are bigger than layers and broiler breeder hens and they are primarily used for meat production. They get a special vitamin rich supplementary food for fast growth rate and broilers reach slaughter-weight at around six weeks of age.[3] Layers produce eggs that are meant for human consumption and do not need as much food as broiler chickens. These eggs are getting sold in supermarkets and they will be used for cooking and eating. Broiler breeder hens are kept together with roosters in order to produce fertilized eggs. The fertilized eggs will be hatched from a breeding machine and the result of this breeding process are small chicks. These chicks will be used as broiler chickens. The broiler breeding hens begin laying eggs after four months of age and on average, a hen lays one egg per day. Fig. 4 shows the three different types of chickens and how they are connected.[4]

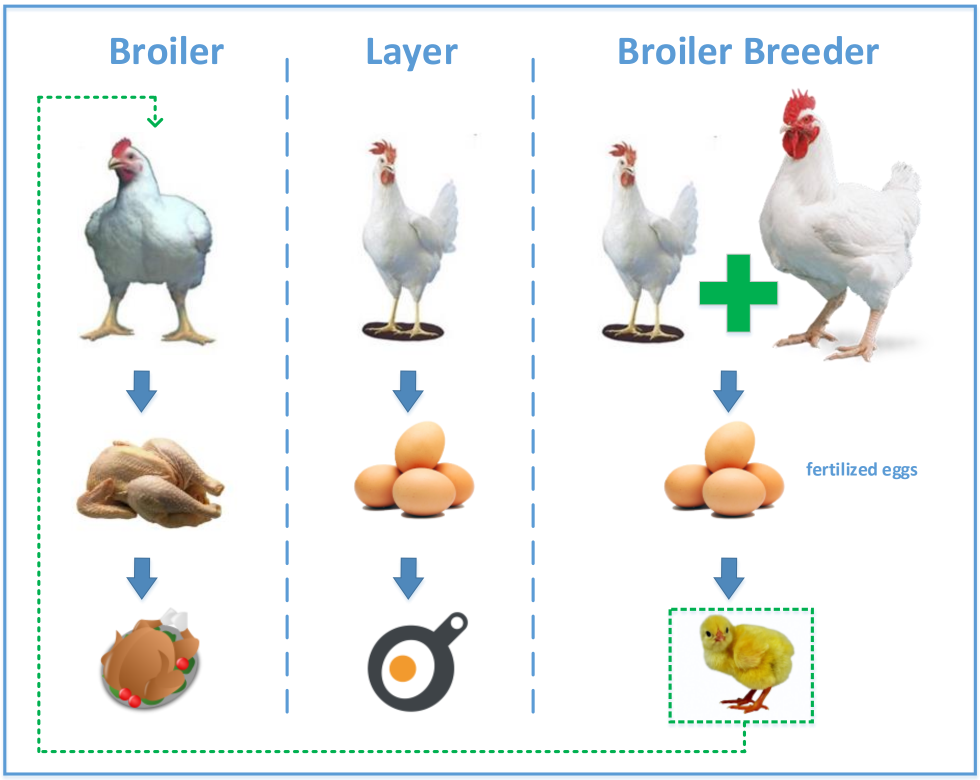


Fig. 4: Different types of chickens, Source: Own illustration

[3] Cf. Arbor Acres (Ed.) (2011), pp. 4-5.

[4] Cf. Far Eastern Agriculture (Ed.) (2016), Online-Source [07.11.2016]

Even though these buildings look similar from outside, the equipment they need for generating the perfect environment for these chickens is different. The broiler henhouse needs less equipment and is therefore cheaper compared to the poultry house for layers, because it needs no egg collection system, which can be very expensive. The broiler breeder management system needs a separate rooster feeding system because the hens and the roosters do not eat from the same feeding supply.[5] The two different feeding types are visualized in Fig. 5. The red box shows the hen feeding supply and the blue box displays the rooster feeding system. The egg collecting system is marked in green.

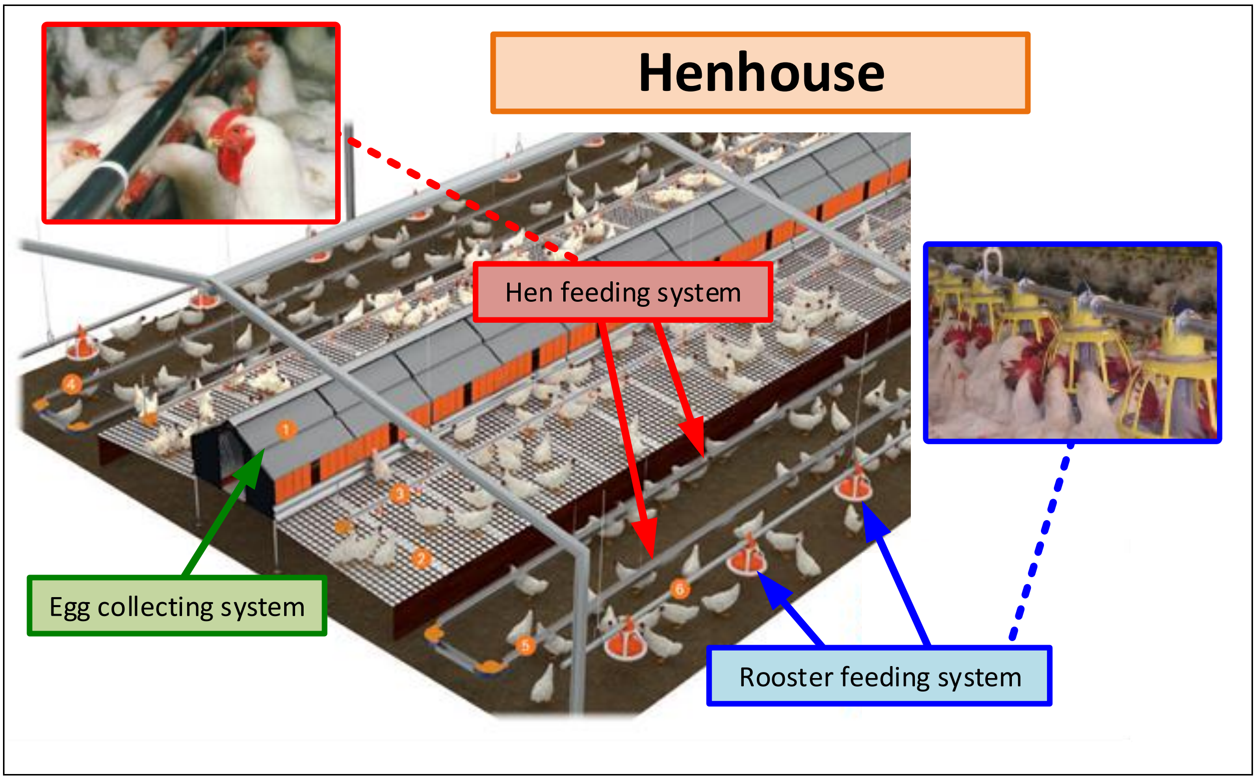


Fig. 5: Henhouse feeding system, Source: Janker (2016), Online-Source [12.11.2016] (modified)

The feeding boxes for hens are not accessible for roosters, because the roosters would steal all the food from the hens, leaving them starving. Also, the roosters get a different composition of feed.[6] The separation of these feeds is solved by making the hen feeding holes too small for the roosters. In order to stop the hens from eating the feed of the roosters, the position of the feeding trays for roosters are located higher above the ground. This makes it impossible for hens to eat the feed of the roosters, as they are smaller.[7]

[5] Cf. Ross (Ed.) (2013), pp. 54-56.

[6] Cf. Hubbard (Ed.) (2015), p. 31.

[7] Cf. The Poultry Site (Ed.) (2016), Online-Source [10.11.2016]

3 CONCEPT OF THE CONTROL SYSTEM

The basic concept of the broiler breeder management system is presented in this part. The user can interact with the control system with a graphical user interface (GUI). The operator has the possibility to control all motors, ventilators, valves and switches from this central point. To make the interaction easier, a big touch panel is used to access all actors and record the data from the sensors, which are installed in the building. Fig. 6 depicts the basic concept of the system, which shows the connection between the user interface, the control system and the electronic components in the henhouse. The computer with the user interface is sending data to the control system, from there the control system generates a signal for the actuators. The result is measured via several sensors and reported back the GUI. For instance, a very useful measurement for the user is the temperature of the henhouse. Due to the sensors in the henhouse, the temperature can be measured and the control system sends a corresponding value back to the user interface, where the value is shown on the screen.

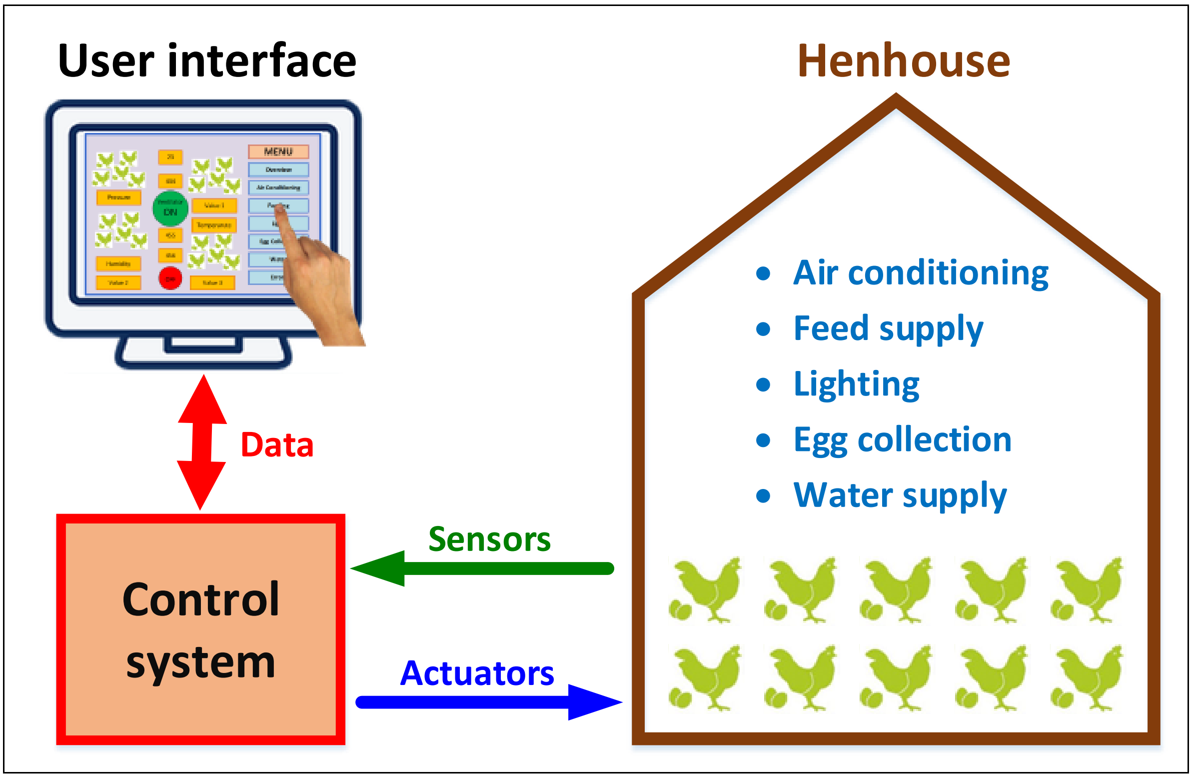


Fig. 6: Basic concept of the broiler breeder management system, Source: Own illustration

For this project, we choose an industrial CPU which is very common in the industry sector and simple to handle. The reason for using this CPU is that these control units are reliable and the software to program the CPU is powerful and affordable. A lot of companies who develop and create control units for the agricultural section use their own software. Usually, it is very difficult to adapt new components to the system without a specially educated programmer from the manufacturer company. Therefore, choosing a common industrial programming software makes it easier for engineers to adapt additional components and write new software.[8]

[8] Cf. Plaßmann/Schulz (2009), pp. 588-589.

All the quantity names and their corresponding symbols and the unit names along with their corresponding symbols are shown in Tab.1.

Quantity		Unit	
Name	Symbol	Name	Symbol
Electric potential differece	V	Volt	V
Electric current	I	Ampere	A
Electric resistance	R	Ohm	Ω
Length	l	Meter	m
Time	t	Second	s
Pressure	P	Pascal	Pa
Temperature	T	Kelvin	K
Froce	F	Newton	N
Frequency	f	Herz	Hz

Tab. 1: SI Units, Source: Plaßmann/Schulz (2009) p. 736.

Due to the fact that this project is made for an agricultural holding in Austria and according to the customer requirements, the unit for temperature will be used in degree Celsius.

$$T_{(°C)} = T_{(K)} - 273.15 \qquad (3.1)$$

Quantity Name	**Quantity** Symbol	**Unit** Name	**Unit** Symbol
Temperature	$T_{(°C)}$	degree Celsius	°C

3.1 Schematic illustration of the concept

The schematic illustration in Fig. 7 represents the structure of the henhouse with all sensors and actors and will be explained in the follow page.

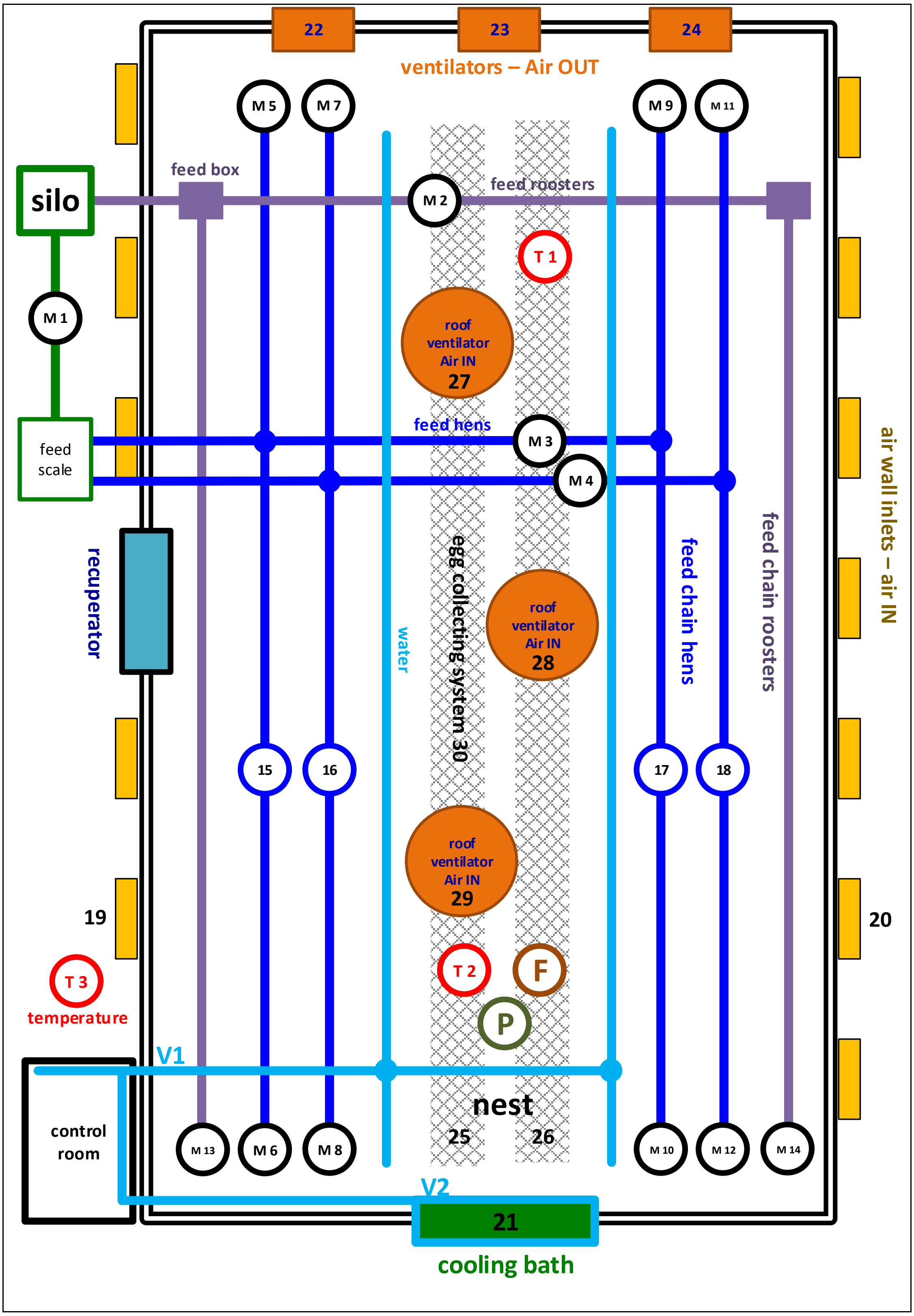


Fig. 7: Concept schema of the broiler breeder management system, Source: Own illustration

This schematic representation is based on the construction plan from Janker, the company who has installed all the equipment in the henhouse and was developed together with the main contact person Josef Taucher from the agricultural holding Taucher. This person is the main user of the already existing control systems from henhouse 1, 2 and 3 and he is going to operate the new control system for henhouse 4. After a lot of meetings, many discussions with the responsible person for the new poultry house and an assessment of the local situation, the output was this schematic plan. The water supply system for the henhouse needs several magnetic valves in order to control everything. Janker did the selection of all motors and magnetic valves, because they know exactly which hardware is supported by their products.

Fig. 7 illustrates all important electrical components for the broiler breeder management system and gives a good overview of the positioning of these components in the henhouse. As shown in the bottom left of the concept schema, there is a control room which will be used for the electrical distribution box, the central processing unit and the computer with the user interface. This distribution box has been built by a company which also installed all the wires, lamps and motors in the henhouse. In order to control all the components in the henhouse and to get all the systems working, the following electrical components are required.

- Control room with a distribution panelboard box
- Computer with user interface
- Feeding motors
- Ventilation motors
- Water pump
- Magnetic valves
- Temperature sensors
- Pressure Sensors
- Humidity Sensors
- Measurement transducer
- Switches
- Limit Switches [9]

One aim of this project is to select a CPU, which is going to suit the broiler breeder management system and combine the central processing unit with the electrical distribution box. Therefore, a good collaboration with the electrical installation company is important to generate a good control system for the poultry animals.

[9] Cf. Janker (Ed.) (2016), Online-Source [12.11.2016]

3.2 User Interface

The user interface is the connection between the user and the control system. In order to make the interaction as easy as possible, a big touchscreen has been chosen as user interface for this project. The design and the usability of the interface are very important. Therefore, the control buttons are very large and the GUI is kept very simple, in order to help the farmer to handle the user interface easier. Keeping the illustration area clear and easy to understand saves a lot of time and prevents unwanted errors from happening when using the system.[10]

Fig. 8 illustrates the first concept of the graphical user interface, which shows the menu buttons on the right side and several measure values on the left side of the picture. If a different button on the menu side is pressed, the screen on the left side changes to the function settings appropriate to the selected button.

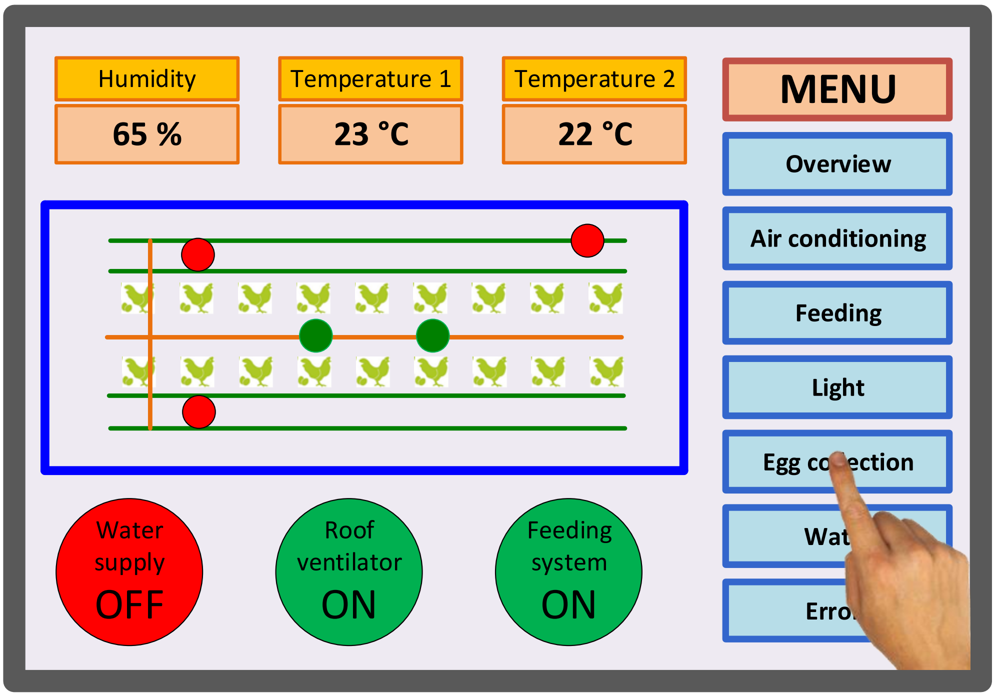


Fig. 8: First concept of the user interface, Source: Own illustration

When a menu button is pressed, the interface shows the most important information about the selected control system. During development, Mr. Taucher can give feedback on the design of the interface and therefore the result is an individual interface for the customer. Moreover, Mr. Taucher can learn to operate the new control system faster, because he supported to generate the design of the user interface.

Furthermore, Mr. Taucher's background is necessary to create the perfect user interface, because he is unhappy about the old interface and knows exactly what needs to be changed. The user can choose between seven menus. The menu button *"Overview"* gives an overview on the most important measure values of the henhouse and the overall state it is in. The *"Error"* button represents errors if there are some problems with the poultry house. The other five buttons lead the user to the main function menus.

[10] Cf. Bokardo (Ed.) (2016), Online-Source [03.11.2016]

3.3 Definition of the required functions

Chapter 3.2 describes the main functions of the broiler breeder management system. It is explained in detail how these subsystems work and what components are necessary. It is very important to understand these subsystems in order to understand the whole control system.

3.3.1 Climate control system

In order to generate and maintain an ideal climate in the poultry house, it is necessary to have an excellent air conditioning system. The system for this project is different to a normal air conditioner in a flat or in a house. If the climate in the henhouse is not ideal, it can decrease the egg laying performance of the chickens enormously. The eggs are the end product of the farmer and eventually he gets money for them, therefore a great climate for the animals is inevitable. However, to cool the inside of the building is only one function of the climate control system, because it also needs to clean the air in the poultry house.[11] The following components are necessary to generate a perfect climate for the poultry animals in the building:

- Ventilation system
- Air wall inlets
- Heat exchanger
- Cooling combs

3.3.1.1 Ventilation system

The poultry house has six big ventilators and three of them are cross-flow ventilators (Fig. 9) which are located on the front of the building. They suck the fresh air from outside through air wall inlets into the building and blow the hot and dirty air to the outside of the henhouse.[12]

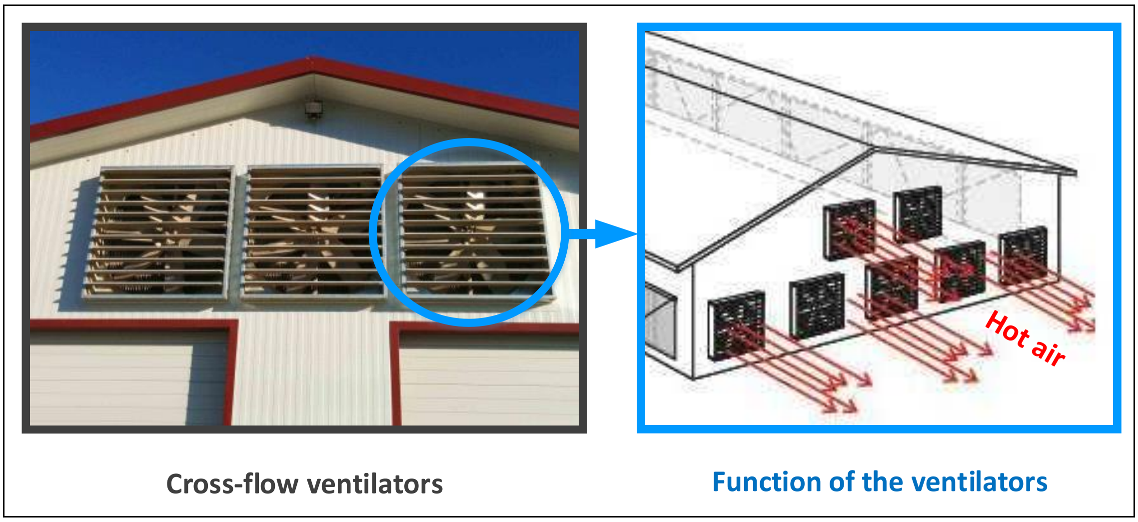


Fig. 9: Cross-flow ventilators, Source: Softek (Ed.) (2016), Online-Source [14.11.2016] (modified)

[11] Cf. Iowa State University of Science and Technology (Ed.) (2013), p. 22.

[12] Cf. Ross (Ed.) (2013), pp. 111-112.

The main function of the ventilation system is to get rid of the hot air inside the building, but there are also additional tasks that the system has to do. Feathers are in the air in the henhouse and congest the water pipes and feed boxes. This affects the water pumps or motors and stops them from working.

The climate control system, which includes many ventilations has the assignment to clean the air and transport feathers and dust out of the building. On the roof of the building, there are three ventilators (Fig. 10) and they are mounted on the highest position of the roof where the hottest air is. [13]

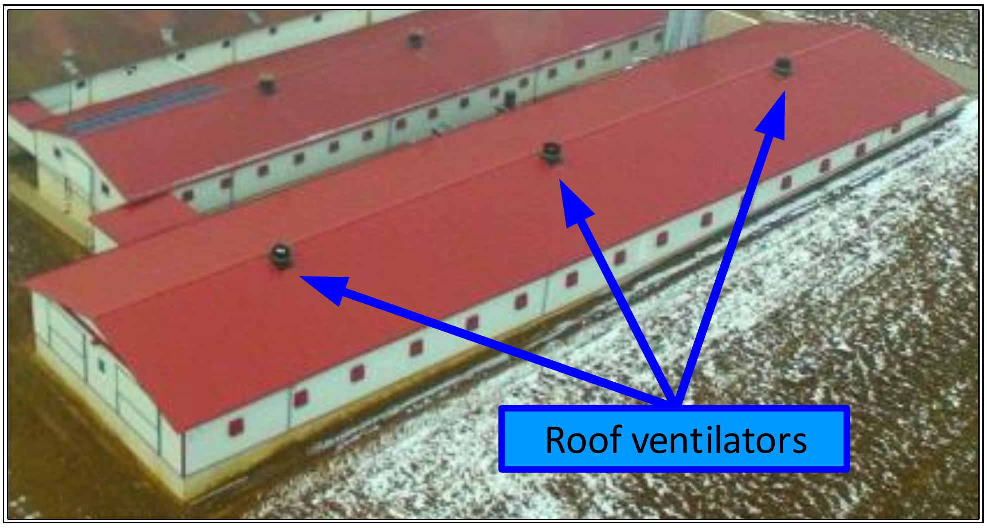


Fig. 10: Roof ventilators, Source: Own illustration

Every one of these six ventilators is separately controlled and it is possible to save power by turning them off or control their power levels. It is not always required that all of these ventilators are running at the same time. However, it is only possible to regulate the power of the roof ventilators because they are the more important devices. The cross-flow ventilators can only be switched on or off and it is not feasible to regulate the power level.[14]

[13] Cf. Leeson/Summer (2009), pp. 233-234.

[14] Cf. Arbor Acres (Ed.) (2011), pp. 39-40.

3.3.1.2 Air wall inlets

The henhouse has on both sides a lot of air wall inlets, which are very important for the ventilation system, because the fresh air flows from the outside through these holes in the henhouse. Fig. 11 shows the air wall inlets from the henhouse ST4. The metal boxes on the wall are the air wall inlet boxes. They have a door on the bottom of the box where air can get into the building if the door is open.

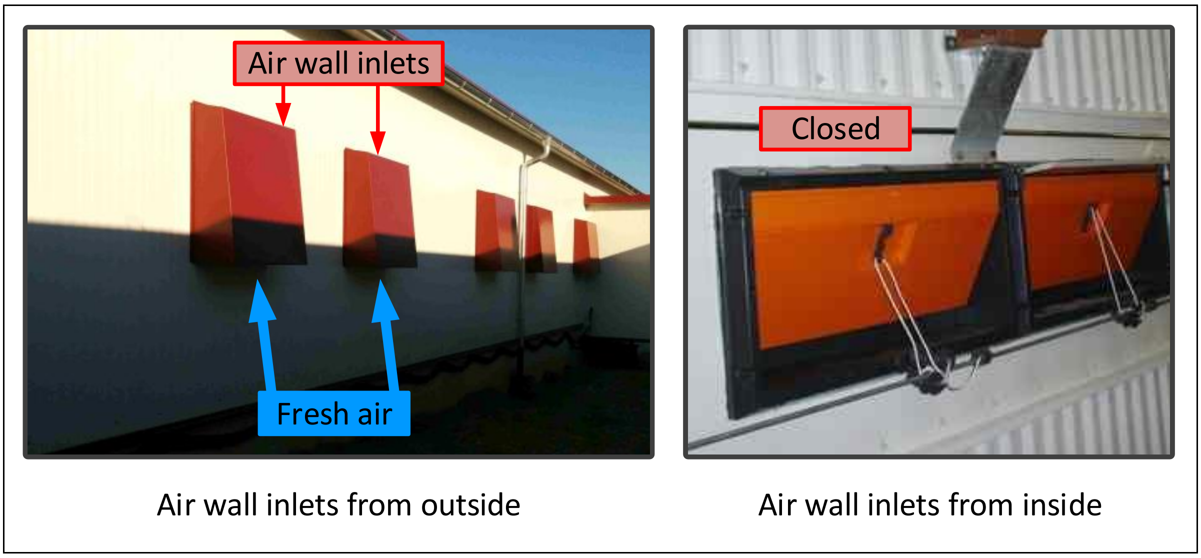


Fig. 11: Air wall inlets, Source: Own illustration

The big cross-flow ventilators on the front side are only open when the temperature in the building is very high, otherwise only the roof ventilators are running because most of the hot air is directly under the roof.[15] Fig. 12 illustrates how the ventilation system works if the cross-flow ventilations are closed. The roof ventilation sucks the fresh air from the outside through the inlets, making sure that the animals inside breath good air. The polluted, hot air leaves the building through the roof.[16]

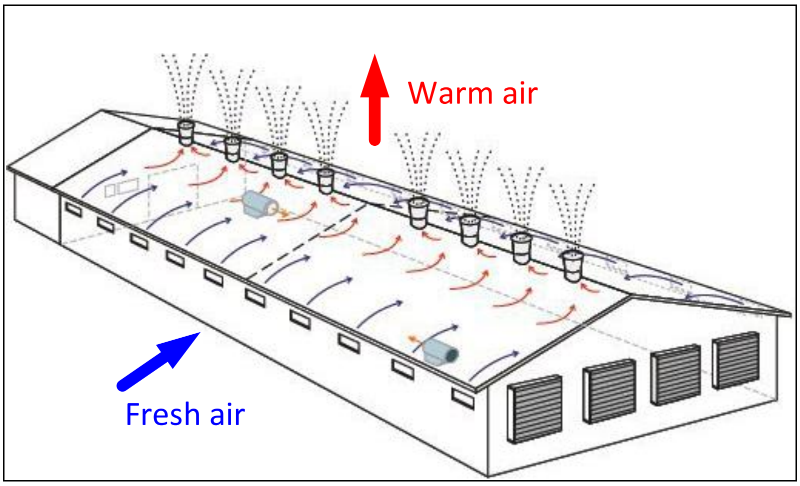


Fig. 12: Function of the air wall inlet system, Source: Softek (2016), Online-Source [14.11.2016] (modified)

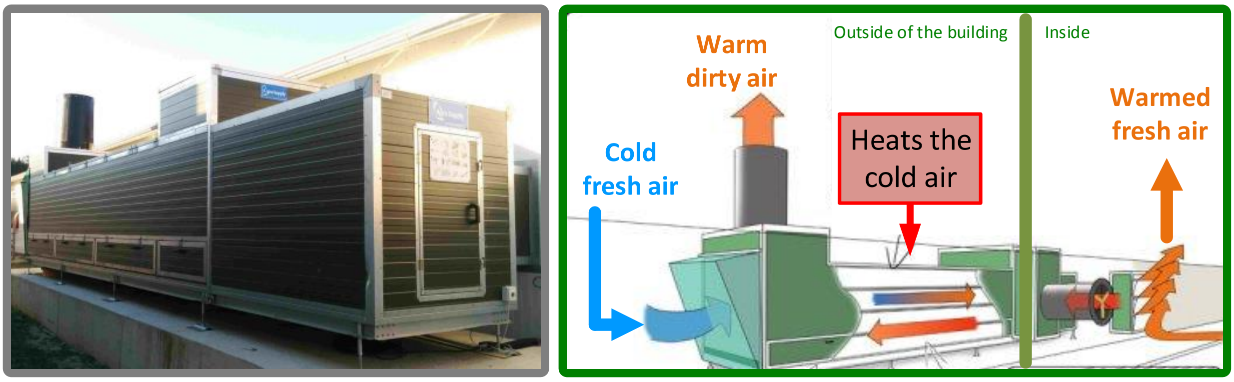
[15] Cf. Lohnmann (2011), p. 25.

[16] Cf. Ross (Ed.) (2013), p. 114.

3.3.1.3 Heat exchanger

In the winter when the outdoor temperature is very low, the ventilators must not suck the extreme cold air from the outside to the inside of the building. This cold air is very unhealthy for the hens and the roosters. If the cold air is blown directly at the animals, eventually they will get sick. For this reason, the henhouse needs a heat exchanger, to bring warm, fresh air in the poultry house.

The heat exchanger, which is illustrated in Fig. 13, will be used in winter when it is extremely cold outside. This device heats the cold, fresh air from outside with the warm air from inside, without mixing them. With this method the animals get new fresh, warmed air in the winter. A ventilator blows this air to a wind sail, which is mounted in the middle of the building and this transports the air to all places in the building.[17]



Heat exchanger from outside

Function of the heat exchanger

Fig. 13: Heat exchanger, Source: Own illustration

[17] Cf. Multiheat (Ed.) (2016), Online-Source [18.11.2016]

3.3.1.4 Cooling combs

For this project, two big cooling combs to cool air on very hot summer days are used when the temperature in the henhouse gets too high. These devices are mounted on the backside of the henhouse. There are doors, which are closed in the winter, to protect the cooling combs. Water is necessary for this system, because the water will be used to cool the air for the chickens and roosters. A cooling comb, as shown in Fig. 14, looks like a big honeycomb with a special structure, which is perfect for cooling the air.

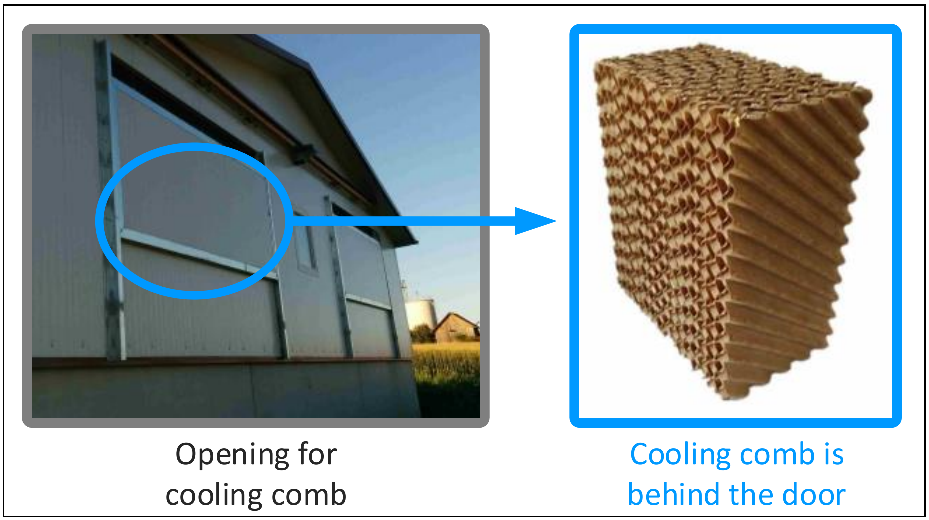


Fig. 14: Cooling combs, Source: Own illustration

Water runs from the top of the comb to the bottom, spreads out and passes through a big surface. At the same time ventilators suck the air from the outside into the building. The warm air flows through the cold comb, cools down and flows into the building as illustrated in Fig. 15. The sprayed water particles contained in the air reach everywhere in the poultry house. This causes a better climate for the animals and helps them to feel better on very hot days.[18]

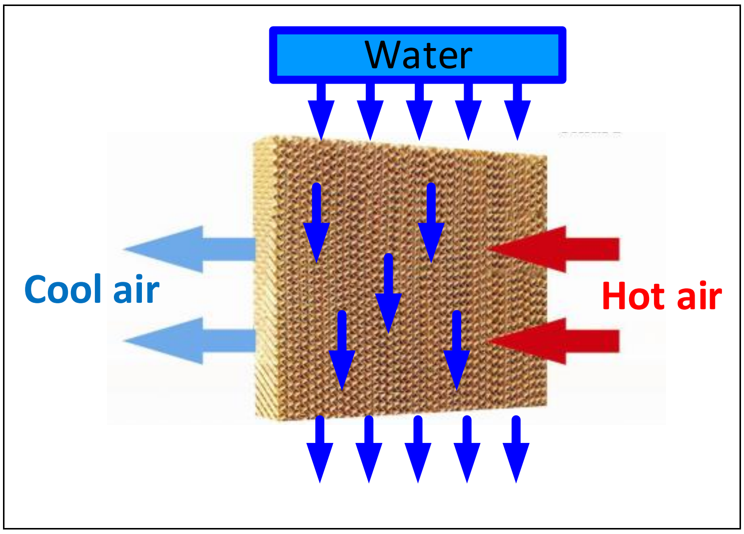


Fig. 15: Function of a cooling comb, Source: Own illustration

[18] Cf. Arbor Acres (Ed.) (2011), p. 38.

3.3.2 Feeding control system

A feeding system includes five main parts to bring the food from the silo to the chickens and roosters:

- Silo
- Silo boot
- Feed line
- Feed sensor
- Drive motor

The silo is used as a food storage for the animals. Once a week, a truck comes to refill this silo. A drive motor transports the feed from the silo to the silo boot to the feed lines (Fig.16). The feed sensor sends a signal to the control processing unit and lets them know if feed is on the feeding pipe.[19]

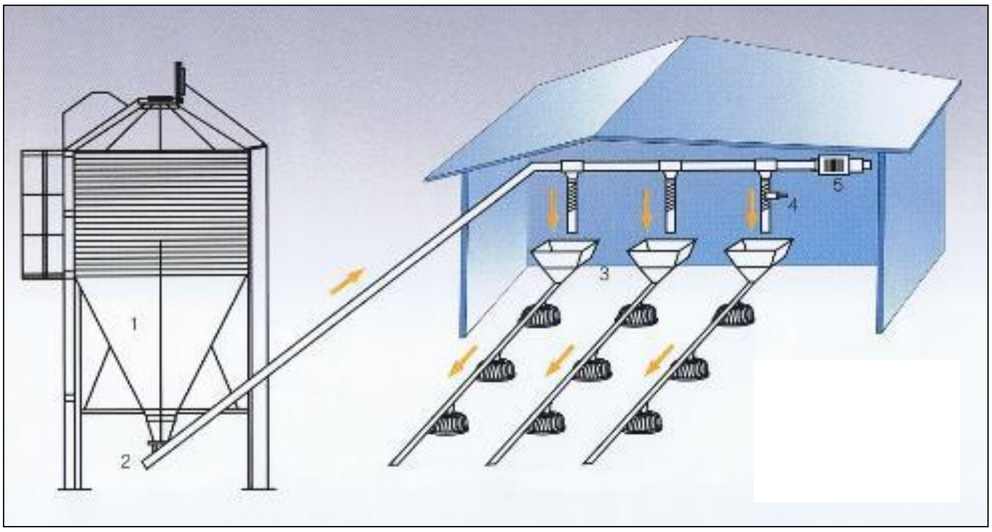


Fig. 16: Feeding system, Source: 5pigroup (2016), Online-Source [12.11.2016]

[19] Cf. Iowa State University of Science and Technology (Ed.) (2013), p. 20.

3.3.3 Light control system

A very important part of the broiler breeder management system is the lighting system.It simulates the daylight for the animals in the building. The henhouse is divided into two parts, but both have the same function and the egg collecting system splits both sides.[20]

Fig. 17 illustrates the left part of the building with two light rows. On the right side of the building, there are also two light rows. The control system can actuate every row separately. This helps the farmer to generate the perfect light conditions for the chickens and roosters.[21]

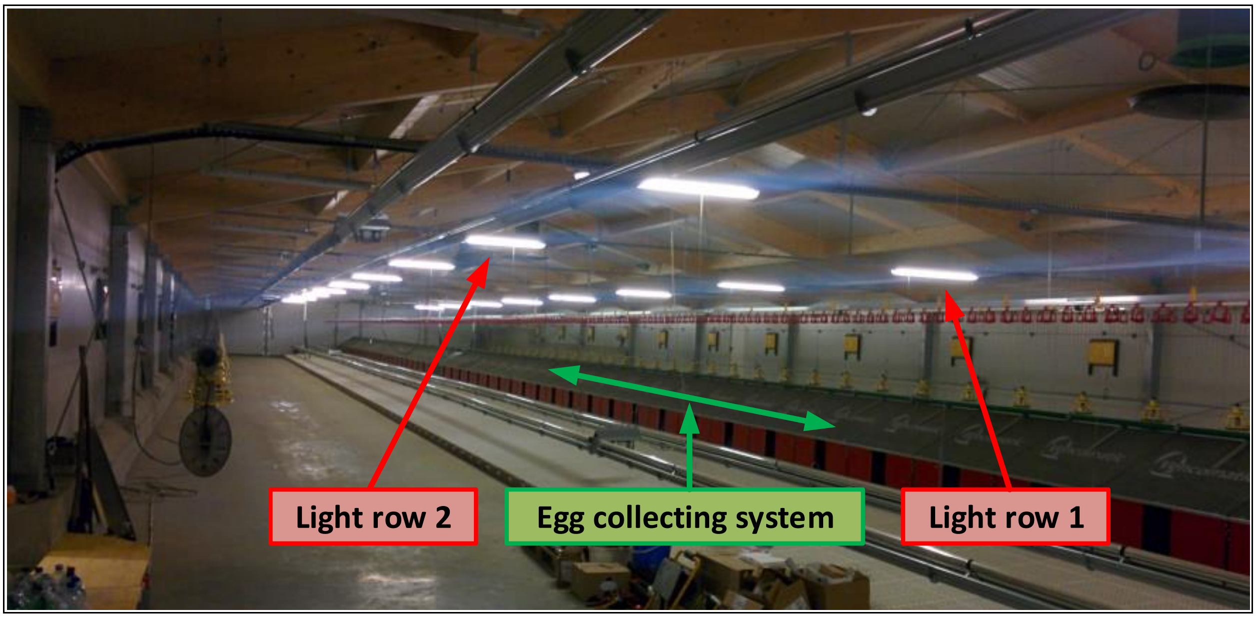


Fig. 17: Overhead lighting, Source: Own illustration

There is a special form of fluorescent lamp used for the lighting system to generate the right brightness in the building. Unfortunately, the animals have no access to daylight, but it is easier and more effective to control the sleeping times without daylight, because this lighting system can be completely controlled by the user and it is not affected by the sun.[22]

[20] Cf. Iowa State University of Science and Technology (Ed.) (2013), p. 21.

[21] Cf. Leeson/Summer (2009), pp. 224-225.

[22] Cf. Ross (Ed.) (2013), pp. 121-122.

For a comfortable awakening and sleeping, the lighting control system uses a special switch-on and switch-off mode which is shown in Fig. 18. When the light starts with 100% power instead of transitioning smoothly to 100% like in the picture, the animals are frightened and they start flying around, which affects the egg laying performance.[23]

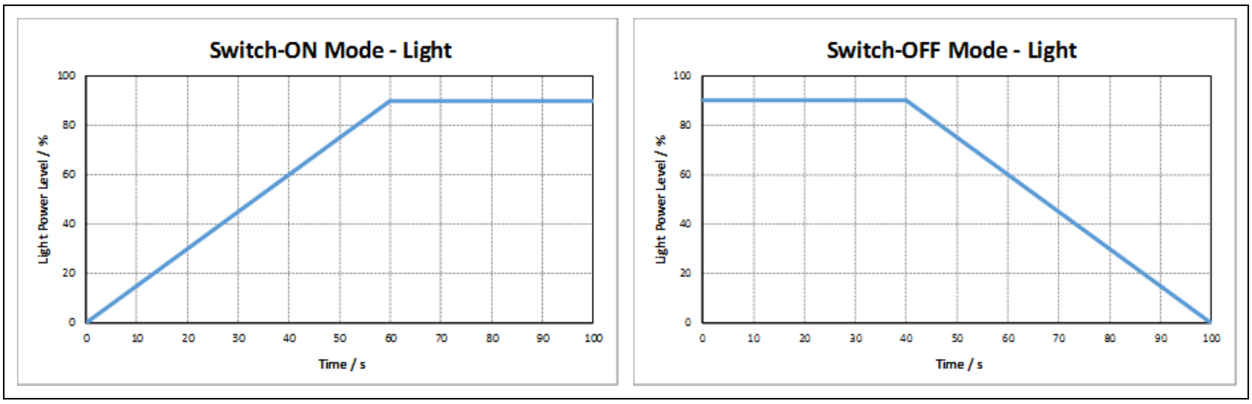


Fig. 18: Switch-ON and switch-OFF modus - light, Source: Own illustration

The two diagrams in Fig. 18 show only examples for a 30 second switch-on process and also 30 seconds for a switch-off process. The user of the broiler breeder management system can change the rump-up and rump-down time.[24]

[23] Cf. Plaßmann/Schulz (2009), p. 913.

[24] Cf. Lewis (2009), pp. 10-11.

3.3.4 Egg collecting System

The henhouse offers a lot of egg laying boxes for the chickens in which they lay their eggs and an automated egg conveyor transports the eggs to an egg sorting room. Fig. 19 shows the transport process from the egg laying box to the sorting room. Finally, an egg sorting robot puts all eggs in big egg cups. This egg collecting system runs once a day and all eggs will be stored in a room. The user can adjust when and how long the egg conveyer works.[25] Before the conveyor starts running, the bottom of the egg laying box raise and the eggs roll on the egg conveyor. After that the conveyor transports all eggs to the egg sorting room.

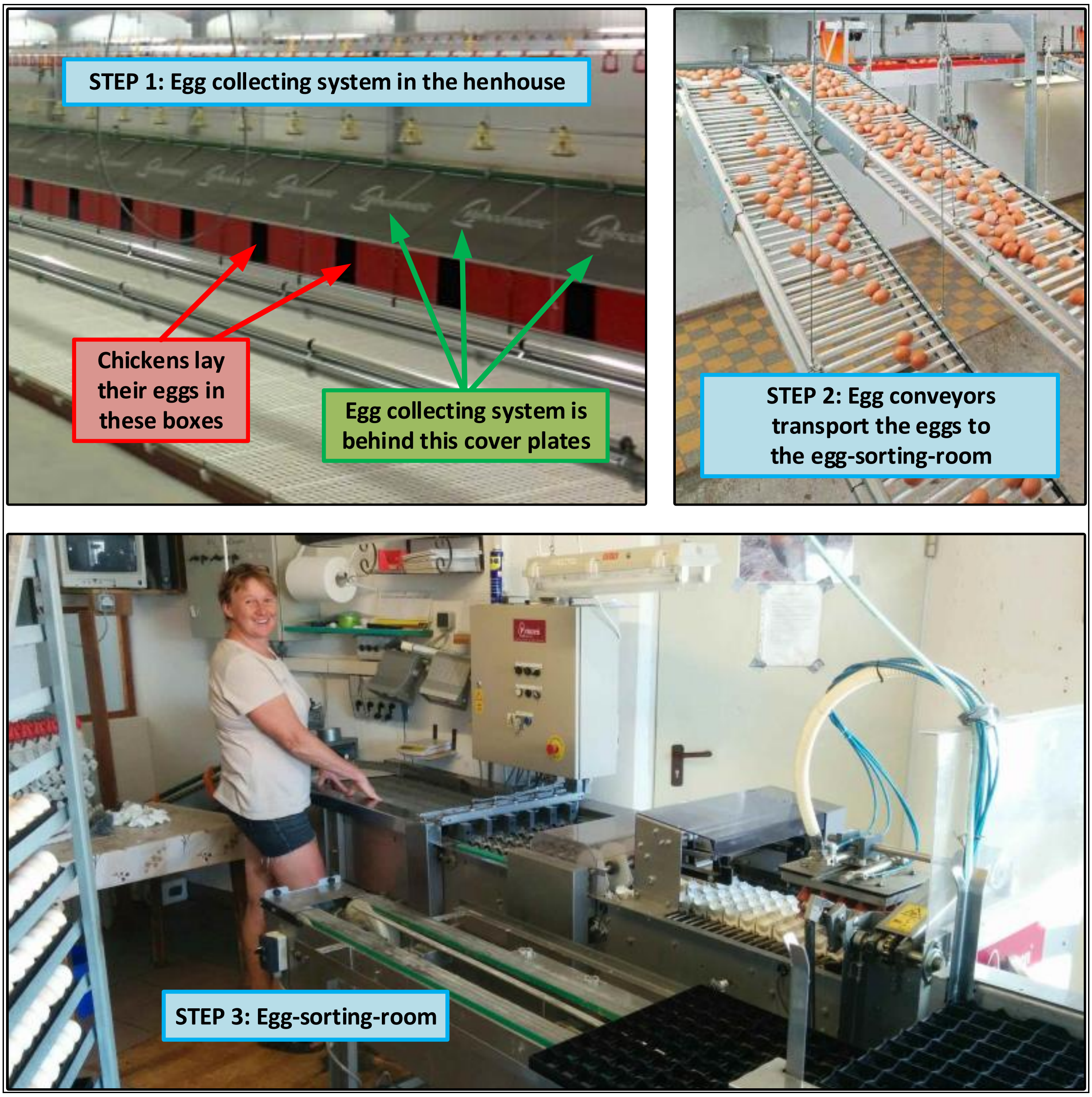


Fig. 19: Function of the egg collecting system, Source: Own illustration

[25] Cf. Iowa State University of Science and Technology (Ed.) (2013), p. 16.

3.3.5 Water control system

The water control system is responsible for the drinking water supply of the poultry animals and also for the cooling combs. This system consists of the following components:

- Magnet valves
- Water mass flow meter
- Water filter
- Vitamin mixer[26]

Fig. 20 illustrates the main parts of the water control system, which are accessed by the central processing unit. The water filter is responsible for clean water and is filtering out impurities from the water. A clean and filtered water is inevitable for the poultry animals to produce a lot of fertilized eggs.[27] Additionally, the system needs a vitamin mixer which has the task of mixing the drinking water with vitamins that helps the chicken's health and egg production.[28] A water mass flow meter is measuring all the water that the chickens and rooster need for drinking. That is a very important measure value, because the animals have to drink around 2300 liter of water per day and if they drink less than the allowed lower-limit, the system gives an alarm. The user has the ability to set this lower-limit. However, measuring instruments do not measure the water consumption of the cooling combs, as it is not necessary to know the water consumption of the cooling combs. Several magnet valves have the task to open and close all the used water circles.[29]

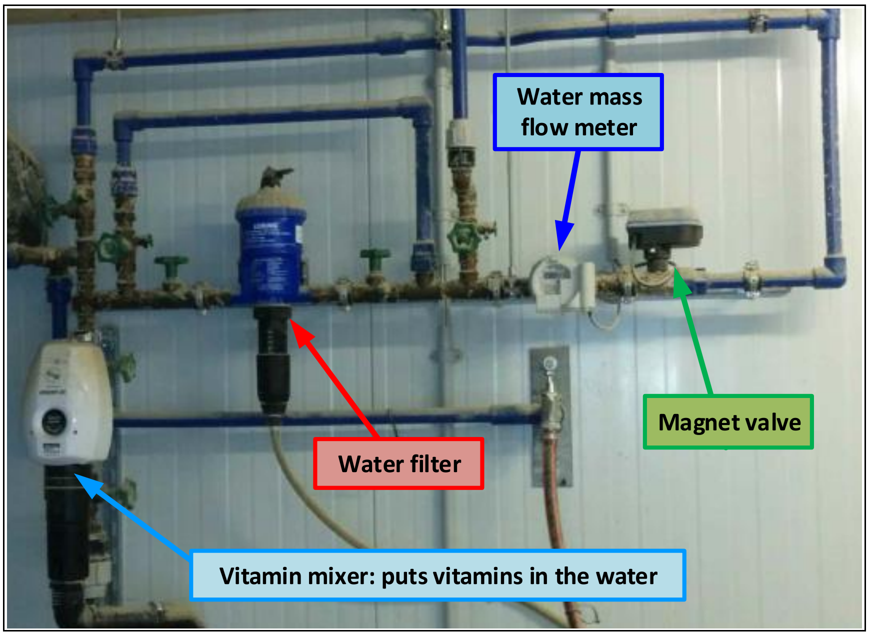


Fig. 20: Water control system, Source: Own illustration

[26] Cf. Cobb (Ed.) (2016), p. 74.

[27] Cf. Lohnmann (2011), p. 26.

[28] Cf. Ross (Ed.) (2013), p. 154.

[29] Cf. Hubbard (Ed.) (2015), pp. 50-51.

4 ANALYSES OF THE ELECTRONIC COMPONENTS

There were many researches made about all necessary electronic components for the broiler breeder management system and chapter four lists the most important parts of this project. Moreover, the basic functions and the reasons why these components have been chosen, are explained in this chapter.

4.1 Central unit processor

Due to the fact that the central processing unit S7-1200 (Fig. 21) from the company Siemens has a wide area of applications and a lot of powerful functionalities, it has been chosen for the broiler breeder management system. The following points list the main reasons for the selection of this product:

- The CPU can be used for a lot of different automation applications
- It has a compact design and fits in every distribution box
- The S7-1200 has a very good price-performance ratio
- Functions of the S7-1200 are completely dependable
- There are a lot of additional modules available
- The Windows-based programming software enables a flexible configuration
- High speed INPUT and OUTPUT channels
- An integrated power supply is included[30]

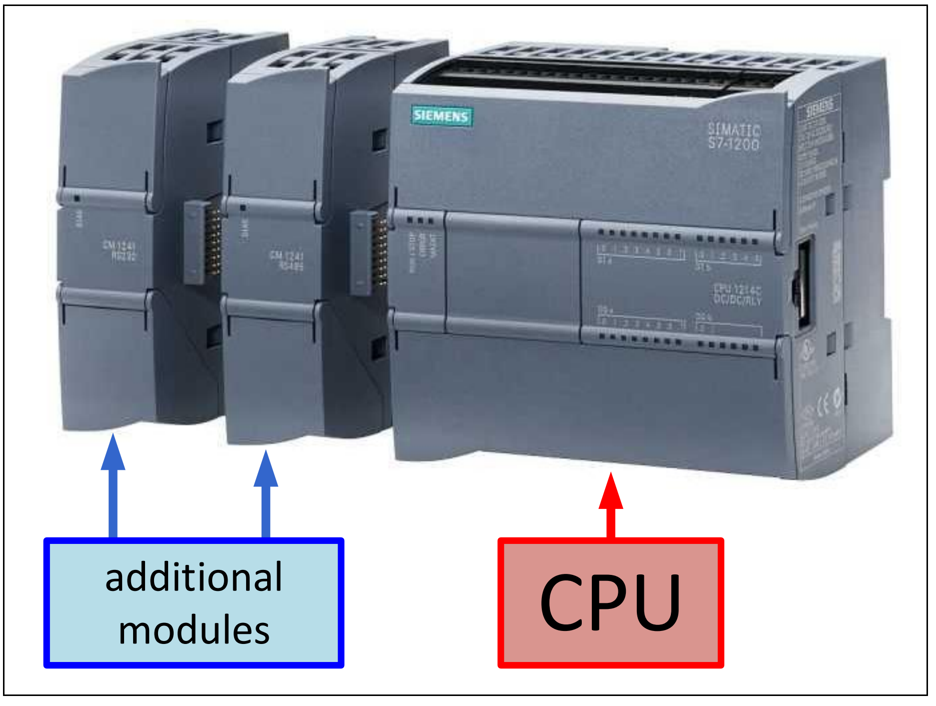


Fig. 21: Siemens S1200 with additional models, Source: Emt-Systems (2016), Online-Source [10.11.2916] (modified)

[30] Cf. Siemens (Ed.) (2016), Online-Source [14.11.2016]

The exact model that has been used in this project is the Siemens S1200-1215C with the article number 6ES7215-1BG40-0XB0. The power supply of this CPU is 24 VDC and it has the following inputs and outputs:

- 14 digital inputs
- 10 digital outputs
- 2 analog inputs
- 2 analog outputs

Fig. 22 shows the wiring plan of the S7-1200 basic model S1200-1212C. The voltage supply of the CPU is 120-240 VAC and that makes it easier to use the system without a 24 VDC power supply.[31]

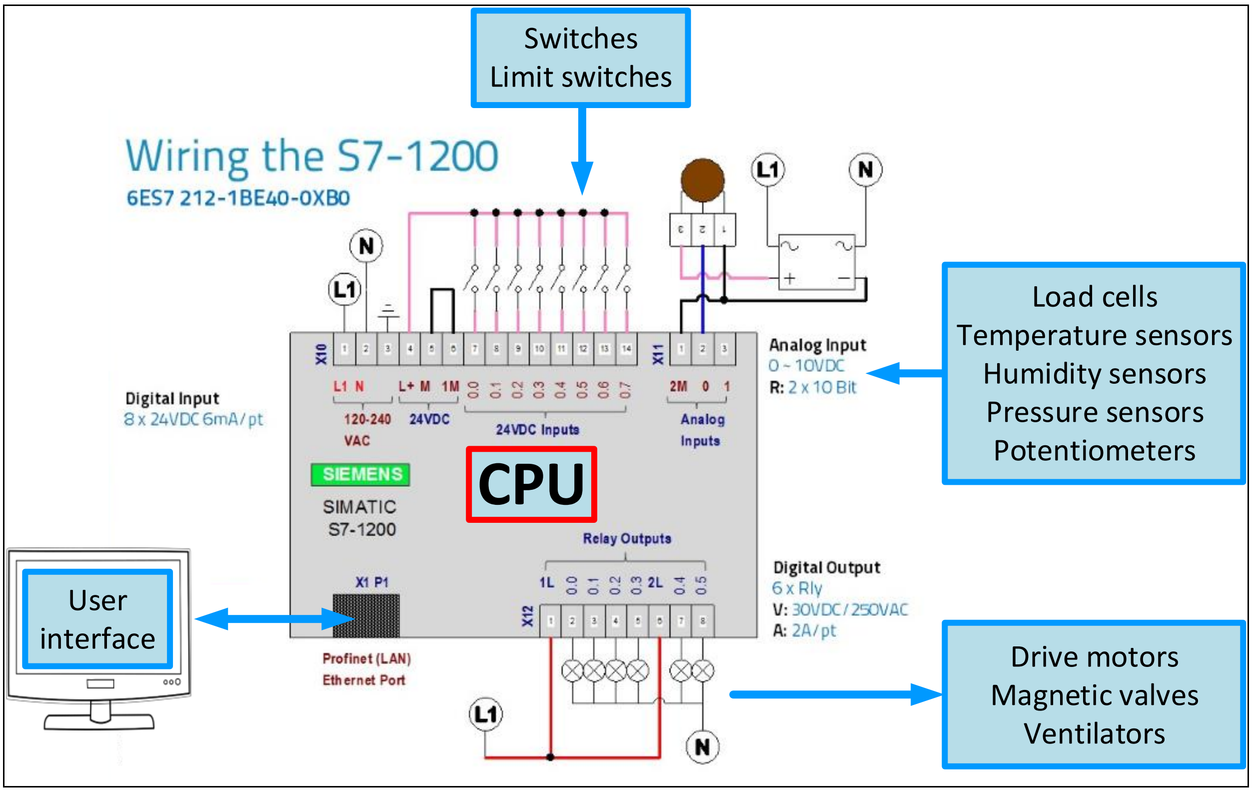


Fig. 22: Wiring plan S7-1200 basic model, Source: Evlos (Ed.) (2016), Online-Source [01.11.2016] (modified)

The whole broiler breeder management system needs a lot of sensors and actors to control all of the components in the building. This is the reason why more modules are required and the CPU alone is not enough. The following additional modules for the S-1200 have been used:

- Analog INPUT module
- Analog OUTPUT module
- Digital IN module
- Digital OUT module

[31] Cf. Siemens (Ed.) (2016), Online-Source [14.11.2016]

- GSM[32] communication module

The software TIA[33] Portal V13 (Fig. 23) from Siemens is the perfect software to create the program for the control system. Furthermore, this powerful programming software allows the user to generate a graphical user interface, which is important for a comfortable control of the henhouse.

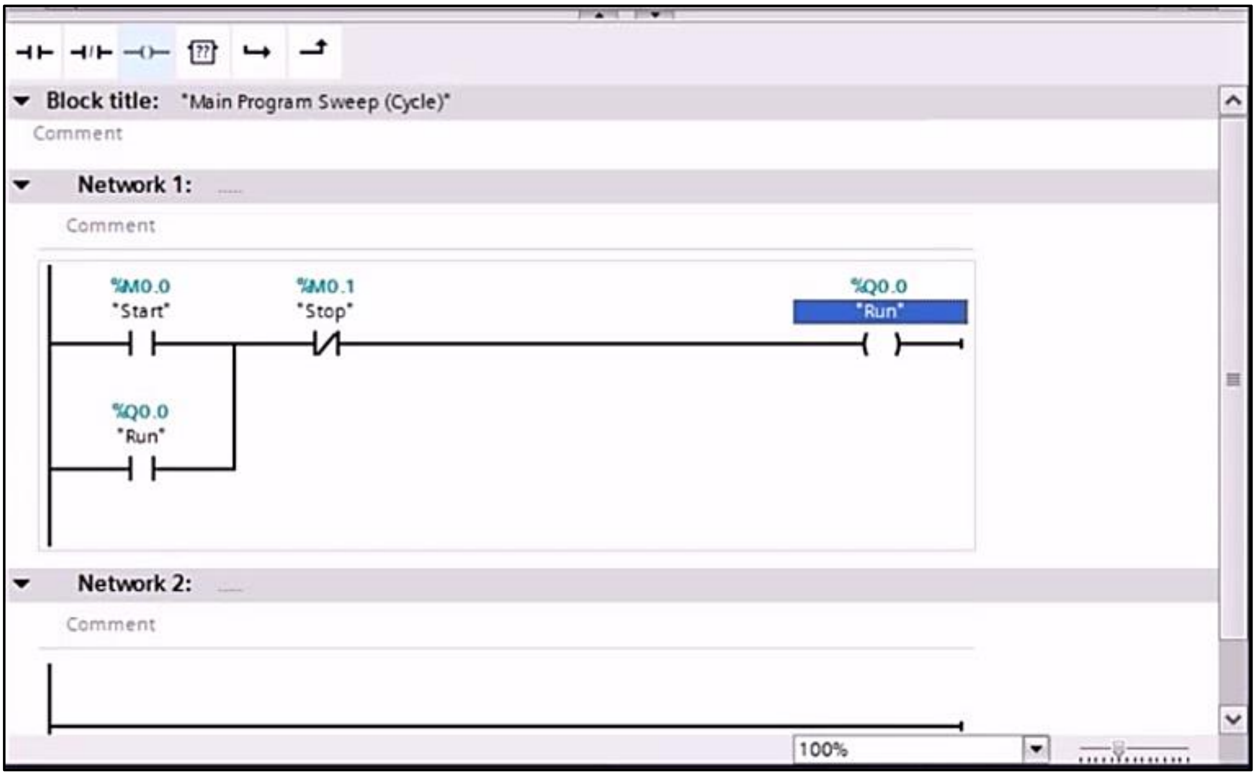


Fig. 23: Siemens TIA Portal V13, Source: Siemens (Ed.) (2016), Online-Source [14.11.2016]

TIA Portal V13 makes it possible to implement a lot of different additional modules. Moreover, the user interface is very clear and you can create programs with STL[34], FBD[35] and LAD[36].

[32] GSM = Global System for Mobile Communications

[33] TIA = Totally Integrated Automation Portal

[34] STL = Statement List

[35] FBD = Function Block Diagram

[36] LAD = Ladder Logic

4.1.1 Additional CPU modules

Additional modules can be easily connected to the main CPU. Each extra module adds features and power to the whole system. There is a limit to how many modules can be added, but the added modules are more than sufficient to accomplish all necessary tasks.

4.1.1.1 Analog input module

The used CPU S1200-1215C from Siemens has two analog input channels. In this case, for an acquisition of all measured sensors there are more than two analog inputs necessary. The additional analog input module can be connected to the main CPU and has to be configured in the software settings. Fig. 24 illustrates an analog input module with eight inputs.[37]

Fig. 24: Analog input module 6ES7231-4HF32-0XB0, Source: Siemens (Ed.) (2016), Online-Source [14.11.2016]

This analog input module is used for the following components:

- Temperature sensors
- Load cells
- Humidity sensors
- Pressure sensors
- Potentiometers

However, several of these sensors use a measure transducer between the sensor and the analog input of the module.

4.1.1.2 Analog output module

Analog output modules look similar than analog input modules and they are used for the following components:

- Roof ventilators
- Heat exchanger ventilators

[37] Siemens (Ed.) (2016), Online-Source [14.11.2016]

- Light control system

Roof ventilators cannot be accessed directly from the analog output module. In this case, the module accesses a powerful frequency inverter which actuate the ventilators. The analog output channels are also used to control brightness of the lighting system.

4.1.1.3 Digital input module

The control system need a feedback from all the electronic components in the henhouse and therefore the system needs a lot of digital inputs. For instance, for the safety system, electrical limit switches are used, which send the position or status of the components. Fig. 25 illustrates the wiring plan of a digital input module with 16 inputs. Moreover, all switches that can be activated by a person are also used as digital inputs.[38]

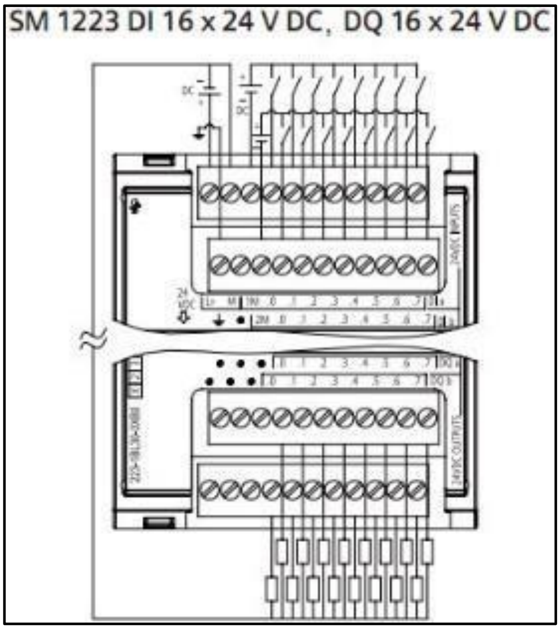


Fig. 25: Digital input module SM 1223 DI 16, Source: Siemens (Ed.) (2016), Online-Source [14.11.2016]

4.1.1.4 Digital output module

The digital output module is used for all feeding drive motors and also for the three big cross-flow ventilators. Furthermore, several motors have two input channels, because they can change the direction of rotation, like the motor that opens and closes the wall inlet. Moreover, this module is used for all magnet valves which control the water supply for the chickens and for the cooling combs.

[38] Cf. Siemens (Ed.) (2016), Online-Source [14.11.2016]

4.1.1.5 GSM communication module

The complete henhouse control system has a complex structure and it is possible that a motor has an error or a sensor can send a wrong signal. If there is an error, the CPU needs a way to warn the farmer and in this case the GSM communication module CP 7212-7 is used.[39] This GSM module supports two main services:

- GPRS = General Packet Radio Service

  This service can be used for data transmission and is handled via the GSM network.

- SMS = Short Message Service

  The module can also send SMS messages to mobile phones.

Fig. 26 illustrates the basic function of the Siemens control system if an error happens. If there is a problem in the poultry house, the GSM communication module sends an error message to the mobile phone of the farmer. Additionally, the CPU activates the alarm horn to warn the people in and around the building.

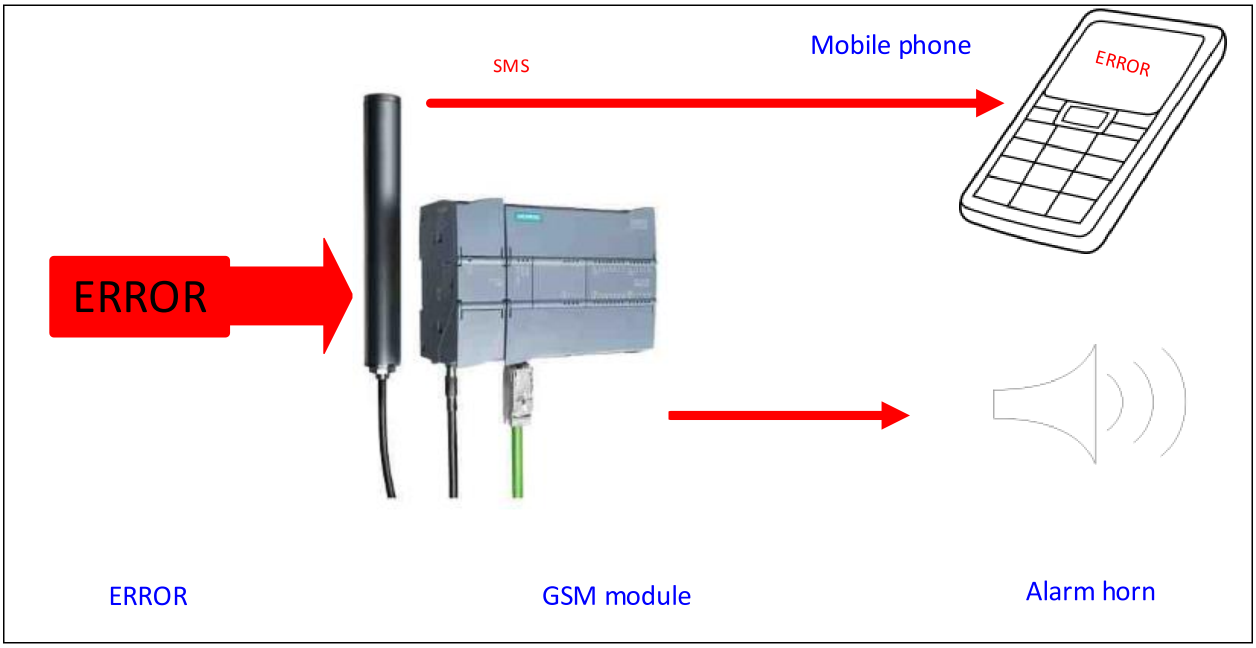


Fig. 26: Basic function of the Siemens GSM module CP 1242-7, Source: Siemens (Ed.) (2016), Online-Source [14.11.2016] (modified)

Additionally, this communication module can be used as a channel to control the CPU from outside via a computer or a tablet.

[39] Cf. Siemens (Ed.) (2016), Online-Source [14.11.2016]

4.2 Sensors

Sensors are the connection devices between the physical environment and the modern electronic measurement technology. Without consideration of the physical measurement principles, there exist passive and active Sensors.

Passive Sensors need auxiliary power for measuring physical values. These sensors change their own electrical properties under the influence of non-electrical quantities. One example is the pressure sensor for this project. This sensor needs an additional power supply to measure physical quantities.[40] Usually, these type of sensors provide very high precision. Fig. 27 illustrates the basic structure of passive sensors.

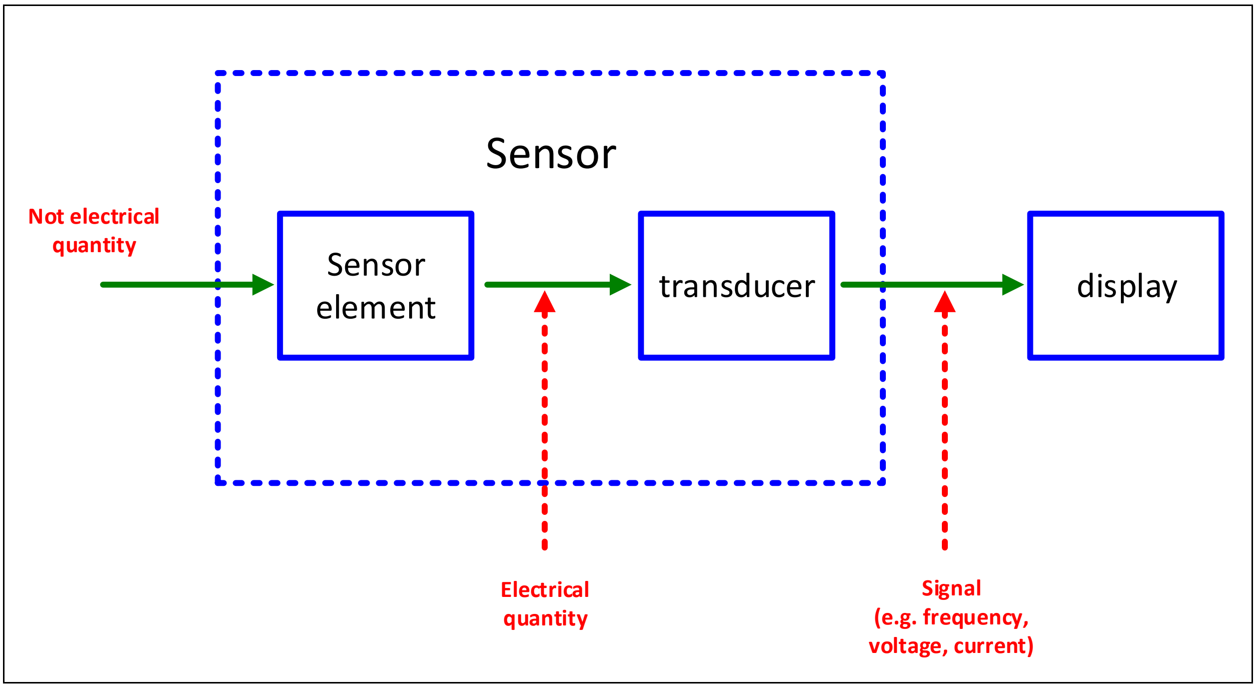


Fig. 27: Basic structure of passive sensors, Source: Parthier (2006), p. 127 (modified)

However, active sensors are energy converters and they convert non-electrical quantities in the electrical quantities. The precision of these sensors are usually lower compared to the passive sensors. Nevertheless, there is no auxiliary power necessary. A thermocouple is an example of an active sensor which produces voltage, because of the thermoelectric effect. The produced voltage is temperature-dependent.[41]

[40] Cf. Parthier (2006), p. 125.

[41] Cf. Parthier (2006), p. 126.

For a good working broiler breeder management system, the CPU needs a lot of different sensors to control the whole henhouse and the following sensors are required:

- Temperature sensors
- Humidity sensors
- Pressure sensors
- Load cells

There are several methods and sensors to measure all these measured values. In this paper, only the selected sensors and their basic functionality will be explained.

4.2.1 Temperature sensors

The measured value of the temperature is necessary for the control of the climate control system.[42] To measure the indoor and outdoor temperature, the resistance temperature detector (RTD), which is composed of certain metallic elements (e.g.: platinum, nickel), is selected.

RTD elements change their resistance value, if the ambient temperature of the resistor changes.[43] Current flows across the resistor and the voltage drop on the resistor is measured and converted to the temperature value. Due to the fact, that RTD elements offer an admirable accuracy over a wide temperature range, they are ideal to measure the temperature in a poultry house.[44] The RTD elements can be manufactured in two different types:

- Wire wound elements
- Thin film elements

[42] Cf. Ross (Ed.) (2013), p. 18.

[43] Cf. Morries (2001), p. 284.

[44] Cf. Parthier (2006), pp. 161-162.

The wire wound RTD (Fig. 28) typically uses a platinum wire, which is wound around a ceramic or glass bobbin. The sensor element of the thin film type is formed by depositing a thin platinum layer onto a ceramic substrate. The thin film element, which is also shown on Fig. 28 is chosen for this project, because this type of temperature sensor is smaller, faster and less expensive than the wire wound model.[45]

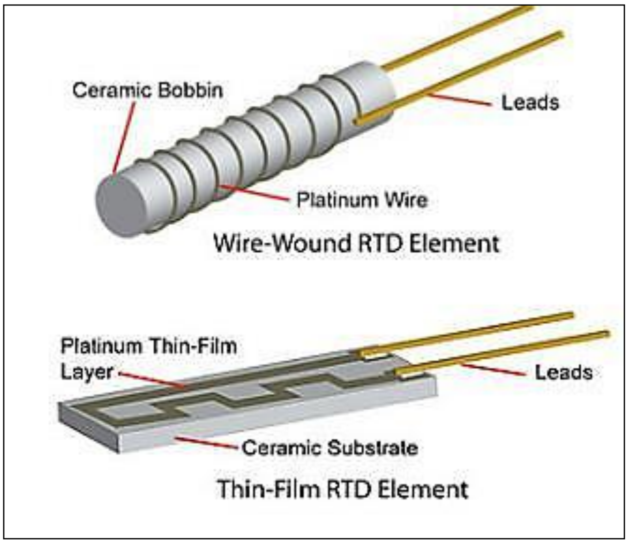


Fig. 28: Wire wound RTD element vs Thin film RTD element, Source: Sensortips (Ed.) (2016), Online-Source [17.11.2016]

4.2.2 Humidity sensors

There exists a lot of different methods to measure the relative humidity of a medium. For this project a humidity sensor for air is used, because the control system needs to regulate the ventilation system by using this value.[46] The chosen humidity sensor is a capacitive polymer sensor, which is perfect for buildings like the henhouse. Due to the fact that the toxic gas concentration (e.g. ammonia) in the henhouse is very low this sensor will not have any problems to work properly. Fig. 29 represent the basic structure of a capacitive sensor.

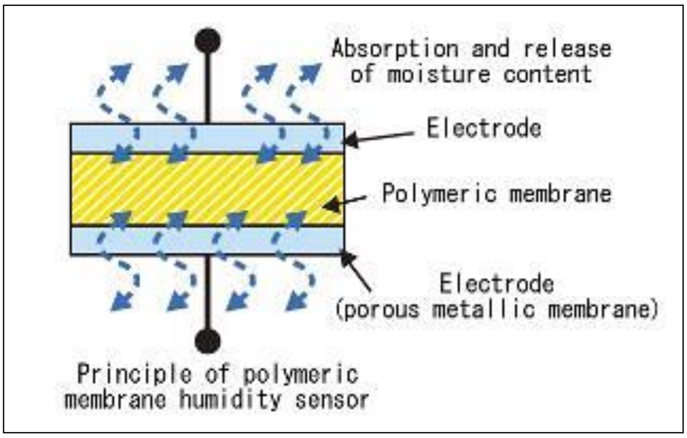


Fig. 29: Principle structure of a capacitive polymer sensor, Source: Apiste (Ed.) (2016), Online-Source [02.11.2016]

[45] Cf. Parthier (2006), p. 162.

[46] Cf. Ross (Ed.) (2013), p. 17.

The middle layer, which is the dielectric medium in the capacitor changes its properties, if the humidity level around the capacitor changes. The changes of the capacity describe the changes of the relative humidity.[47] For this project, the humidity sensor FF-GLT-20MA from the company BB sensors is used and the following points describe the reason for this decision:

- Linearized and temperature compensated humidity measurement relieved measurement data acquisition
- IP 65 enclosure protect the electronic from the dirty ambient conditions in the henhouse
- Different application areas: optimal for raw ambient conditions[48]

4.2.3 Strain gauge load cells

The feeding system of the broiler breeder management system needs a feeding silo, which stores the food for the chickens and roosters. Fig. 30 illustrates the construction of a strain gauge load cell, which has four strain gauges to measure the force acting on the load cell. The three feet of the feeding silo are mounted on the top of the load cells and the weight of the silo generates a force that presses on the load cell.

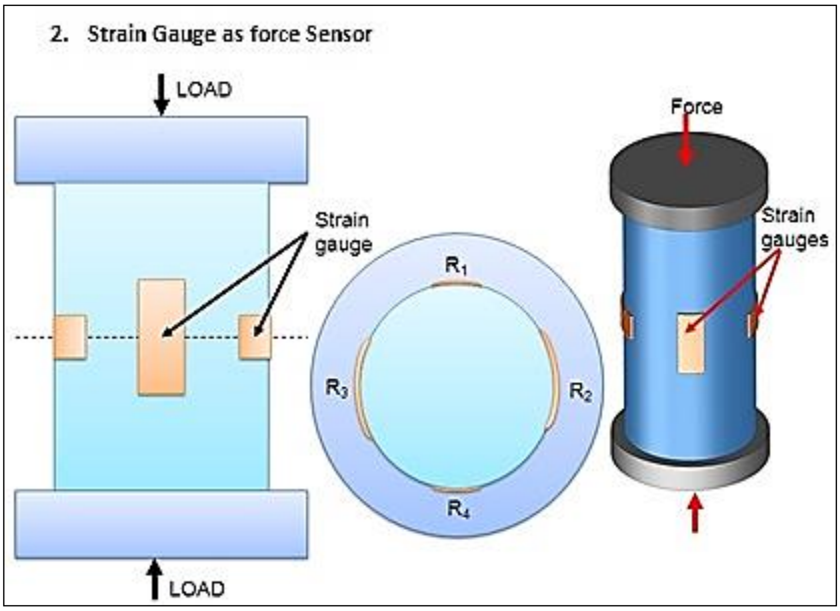


Fig. 30: Construction of a strain gauge load cell, Source: NPTEL (Ed.) (2016), Online-Source [17.11.2016]

If a force presses on the load cell, the form of the metal cylinder changes. Furthermore, the strain gauges, which are fixed on the cylinder changes its electrical resistance during mechanical deformation. These type of load cells are very robust and their load ranges are very big.[49]

[47] Cf. Parthier (2006), pp. 169-170.

[48] Cf. BB Sensors (Ed.) (2016), Online-Source [15.11.2016]

[49] Cf. Plaßmann/Schulz (2009), pp. 783-784.

4.3 Measurement transducer

The analog inputs of the CPU and the additional analog input module can only measure the following input signals:

- Voltage: +/- 10 V DC, +/-5 V DC, +/- 2.5 V DC
- Current: 0-20 mA, 4-20 mA[50]

Not all sensors, which are used for this henhouse, have one of these mentioned output signals. Therefore, two separate measurement transducers are necessary. The load cells and the RTDs need an additional transducer to send the CPU the right signal.[51]

4.3.1 Load cell transducer

The output signal from the load cells (2 mV / V) is very low and cannot be directly recorded by the analog input channel of the CPU. A transducer (Fig. 31) is necessary to convert the measurement signal from the load cells to another signal for the CPU. Moreover, the software, which runs on the CPU, converts the measurement signal from the transducer to a presentable value for the user. Finally, the weight of the food in the silo will be shown on the user interface.[52]

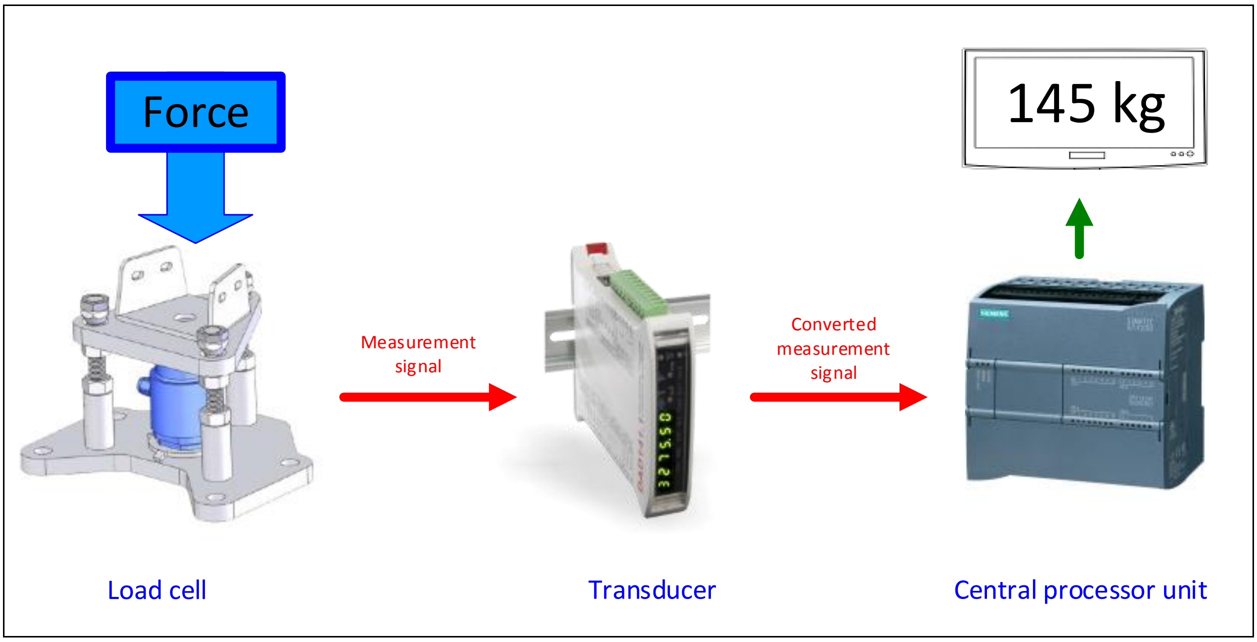


Fig. 31: Communication between load cells and CPU, Source: Own illustration

[50] Cf. Siemens (Ed.) (2016), Online-Source [14.11.2016]

[51] Cf. Plaßmann/Schulz (2009), p. 819.

[52] Cf. Plaßmann/Schulz (2009), p. 783.

Fig 32. represents the electrical connection plan of the load cell transducer.

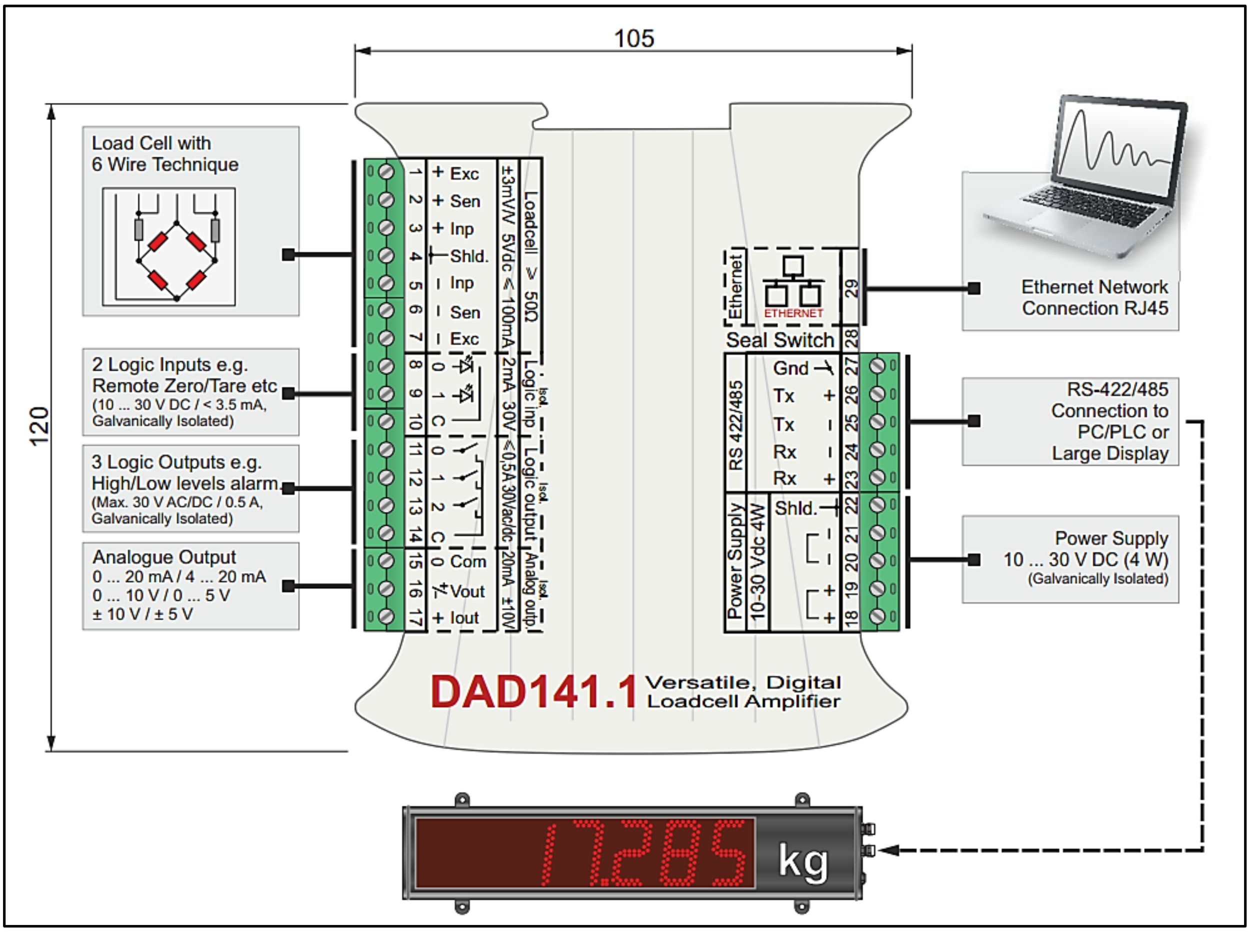
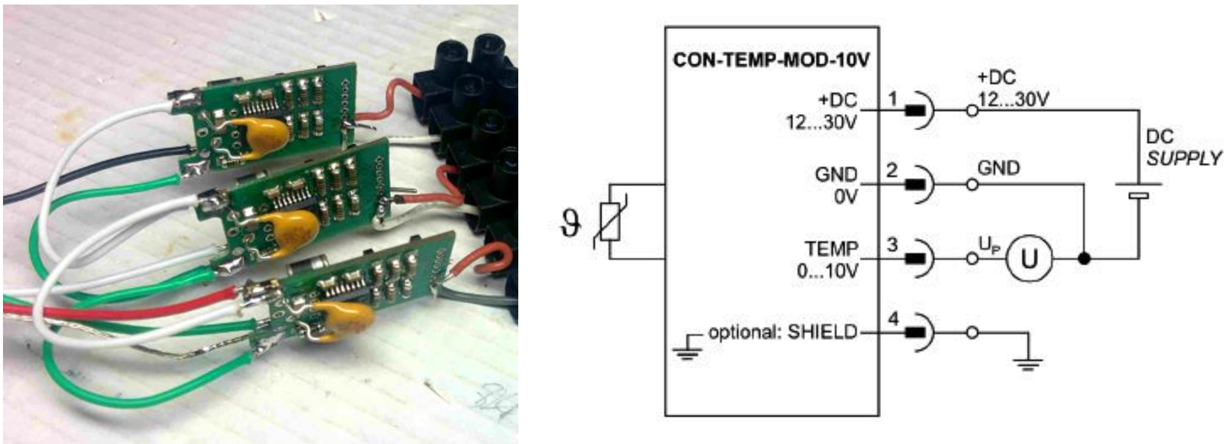


Fig. 32: Electrical connection plan of the load cell transducer, Source: Soemer (Eg.) (2016), Online-Source [16.11.2016]

4.3.2 RTD transducer

For measuring the temperature, a RTD-PT1000 is used. The PT1000 sensor is temperature-dependent and changes its resistance if the ambient temperature varies. Fig. 33 illustrates the measurement transducer, which is used for the PT1000 sensors in the henhouse. This transducer converts the signal from the PT1000 to a voltage signal from 0 to 10 Volt at an ambient temperature of 0 °C.[53]



Transducer for PT1000 | Circuit diagramm

Fig. 33: Transducer for the temperature sensor PT1000, Source: Own illustration

[53] Cf. Mühl (2008), p. 126.

5 DEVELOPMENT OF THE CONTROL SYSTEM

The control system for the broiler breeder management building has been developed in an office room, which is equipped with electronic devices for testing and creation of control systems. Fig. 34 illustrates the private development labor for the broiler breeder control system. The right side of the picture shows the prototype test setup with the central processing unit and the additional modules. In the center of the figure there is an all-in-one computer with a 21.5-inch big touch screen displayed. This computer is used as a user interface for the control system. The CPU and the computer with the user interface are connected via network cable. The second computer on the left side of the picture (marked in green) is used for the software development.

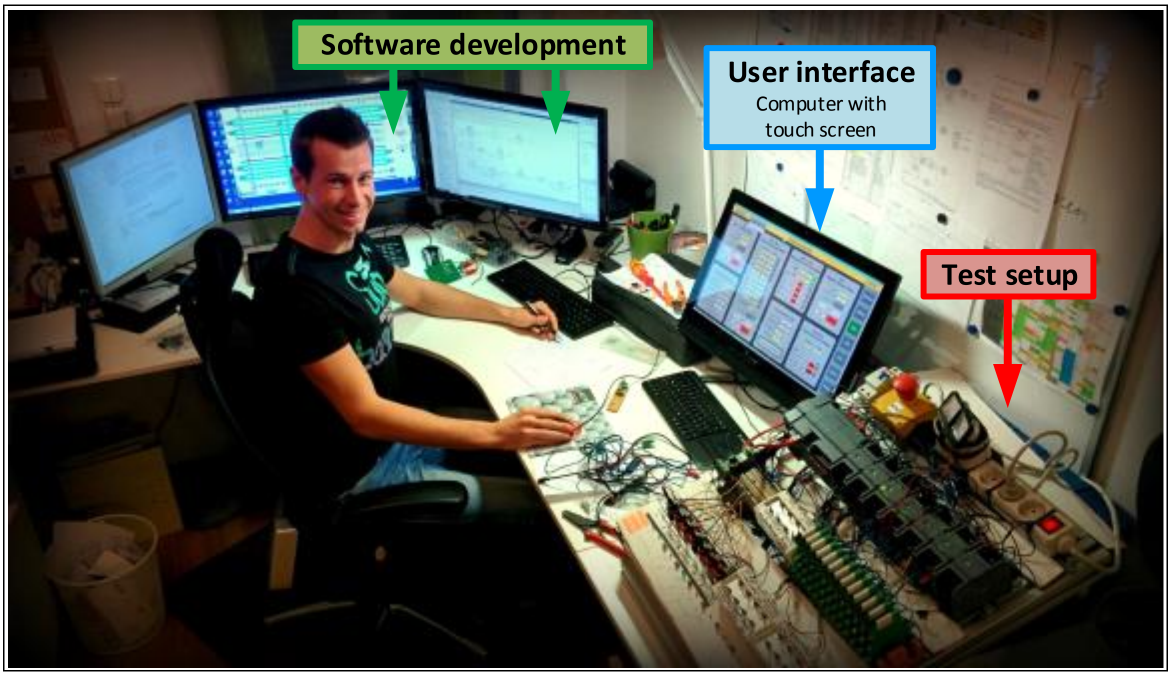


Fig. 34: Development of the broiler breeder management system, Source: Own illustration

With all this equipment, it was possible to develop the program for the control system. Additional to the CPU, the test setup includes a lot of other electronic components, like switches and relays. The complete test apparatus made it feasible to test the software program.

5.1 Tasks of the final control system

The final automated broiler breeder management system handles most of the activities that have to be done in the henhouse. It is very helpful for Mr. Taucher and this system makes it possible to manage such a large amount of chickens and roosters. However, there are also some activities that need to be done manually. The system can handle the following tasks automatically without the help of human beings:

- Feeding the poultry animals
- Supporting them with drinking water
- Controlling the lighting system
- Regulating the climate

Nevertheless, it cannot control the complete egg collecting system, because the egg sorting robot, which is located in the egg sorting room, needs a person that monitors the sorting process. Every day at the same time, the egg collecting system moves the eggs from the egg boxes to the egg conveyor belt, but the control system does not start the egg sorting process. The operator has to start the egg conveyor belt manually. After that, it starts to transport all the eggs to the egg sorter robot. Furthermore, the operator also has to start the egg sorting robot.

Additionally, the operator of the henhouse has to do the following activities:

- Collect all eggs from the floor: A few chickens lay their eggs on the floor and not in the egg boxes.
- Remove dead poultry animals: Every month, several chickens die and they have to be removed.
- Clean the henhouse: All animals in the poultry house will be replaced once a year. Therefore, the operator has to clean the henhouse to prevent diseases from spreading.

5.2 Test setup

The test setup, illustrated in Fig. 35, includes the most important electronic components that are necessary to simulate the functions of the whole control system for the new poultry house. The following components are used for the test setup:

- Digital inputs
  - Switches
- Digital outputs
  - Relays
  - LEDs
- Analog inputs
  - Potentiometer
- Analog outputs
  - Voltmeter
  - Ventilator

It is impossible to mount all electronic devices that exist in the henhouse on this board, because there are too many of them. However, the most important inputs and outputs can be simulated with this test board.

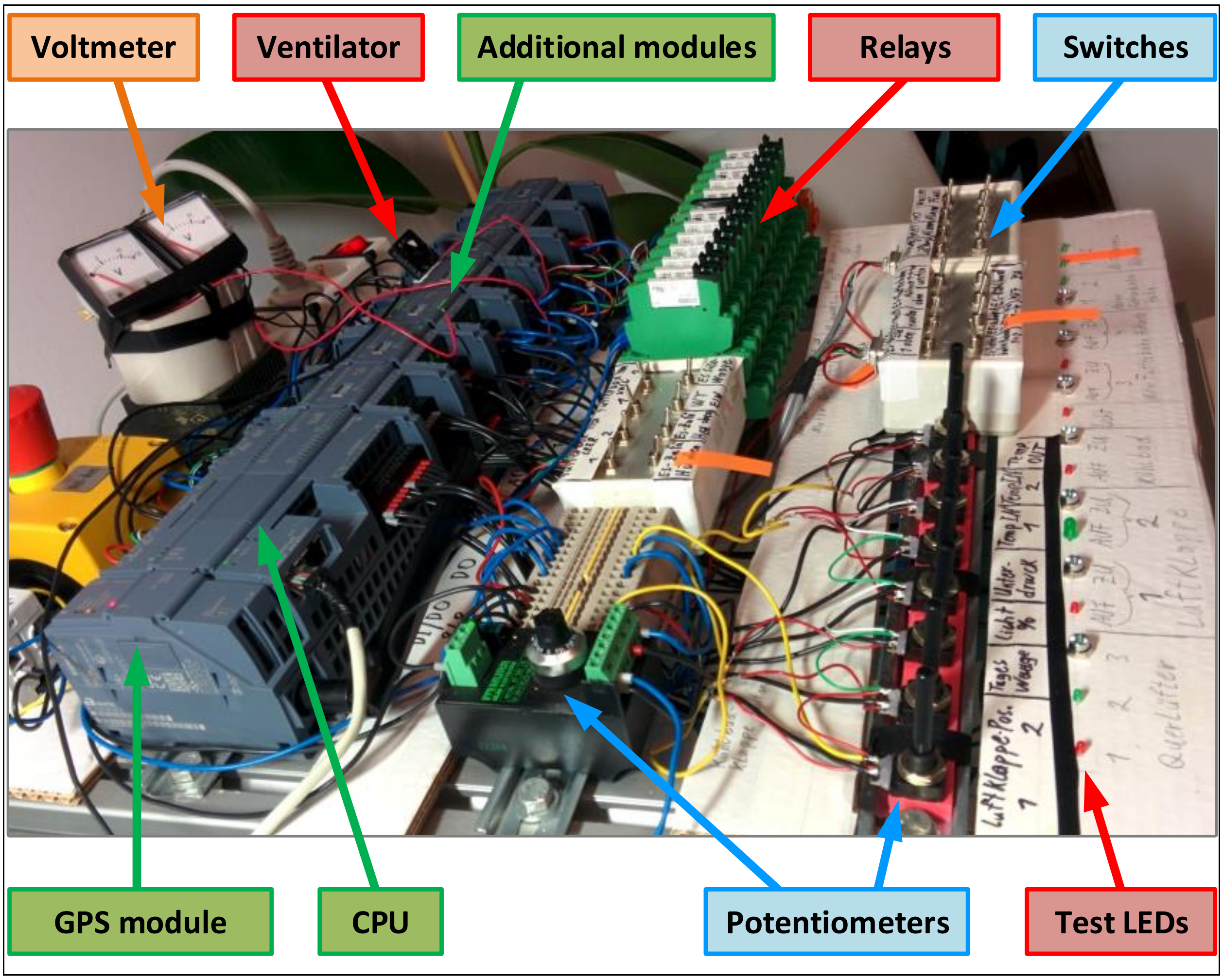


Fig. 35: Test setup, Source: Own illustration

5.2.1 Digital inputs components

There are a lot of limited switches for the feeding system in the henhouse. Every electric motor has, at the least, one limited switch that will be activated, if there are some problems with the motor. Furthermore, all feeding lines have limited switches on both ends of the line. They are necessary, because the CPU needs to know when the feed, which is going to be transported along this line, reaches the end of the feeding line. Most of these switches are simulated in terms of switch boxes on the test board. Furthermore, some switches on the test board are used for emergency shutdown or contactless electronic switches, which are also used for the feeding control system.

Fig. 36 shows a limit switch for the feeding control system. Generally, the feeding lines are not reachable for the poultry animals, because they are lifted and around two meters above the floor. These feeding lines are found on the bottom and reachable for the chickens and roosters during feeding time. For this function, a lot of limit switches are necessary.

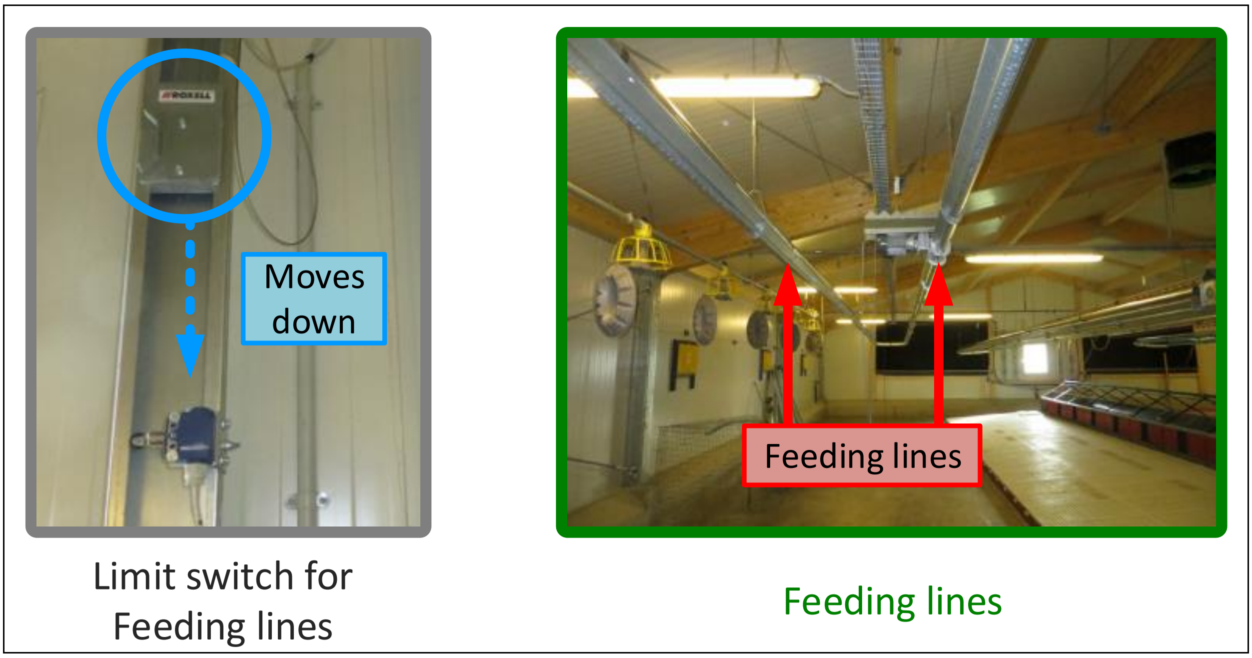


Fig. 36: Limit switch for feeding control system, Source: Own illustration

The limit switch has a small wheel on the end of the switch arm and the metal sledge moves down and activates the limit switch. The metal sledge reaches the switch, when the feeding lines are on the highest acceptable point in the building. Therefore, the limit switches are very important for the control system.[54]

[54] Cf. Janker (Ed.) (2016), Online-Source [14.11.2016]

As shown in Fig. 37, a limit switch can be used in two ways. All safety switches and limit switches for this project are normally closed. It is safer for the complete system to use critical switches this way. Basically, the switch is closed, it opens only if somebody or something presses the button. Current flows through the switch and the digital input channel of the CPU can measure the electrical signal, which comes from the limit switch. However, if the switch does not work very well and sends no signal to the CPU, the central processing unit gets a feedback that a problem exists. This way, it is safer, because the CPU can also check the correct functionality.

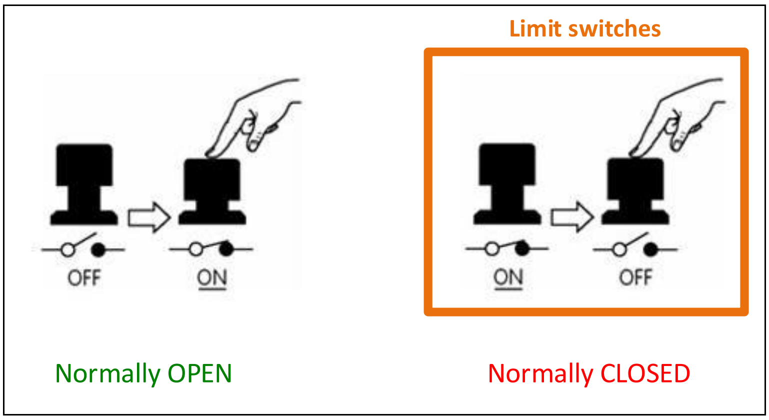


Fig. 37: Normally open and normally closed switches, Source: Own illustration

5.2.2 Digital outputs components

For the electrical test board, LEDs[55] and relays are used to test the digital outputs. These components make the activated outputs visible by switching a light on. Every light or relay has a short description of its function. Therefore, it was always possible to see exactly what electronic component is active or not.

5.2.3 Analog inputs components

There are several sensors in the henhouse, which send an analog signal to the CPU. It is very important to check the functions of these sensors and which potentiometers will be used. Furthermore, these electronic components are necessary to check the reaction of the system, if some values are changed.

5.2.4 Analog outputs components

Voltmeters and a ventilator are used to check the analog output signal for the first prototype board. The ventilator changes its rotating velocity if the analog output of the CPU changes its value. This mini ventilator represents the roof ventilators in the henhouse. For the cross-flow ventilators, normal relays are used, because they cannot change their power level. The two analog voltmeters illustrate the power level of the two different light rows in the building.

[55] LED = Light Emitting Diode

5.3 Software development

5.3.1 Program structure

The program for the control unit was made with the development software TIA Portal V13 from the company Siemens. Due to the fact that this software is written for an agricultural holding in Austria, the following screenshots in chapter 5.3 and 5.4 from the software program and the user interface are illustrated in German. However, the figure subtitles and the explanations of the representations are in English. Fig. 38 illustrates a screenshot of a part of the program for the control system.[56]

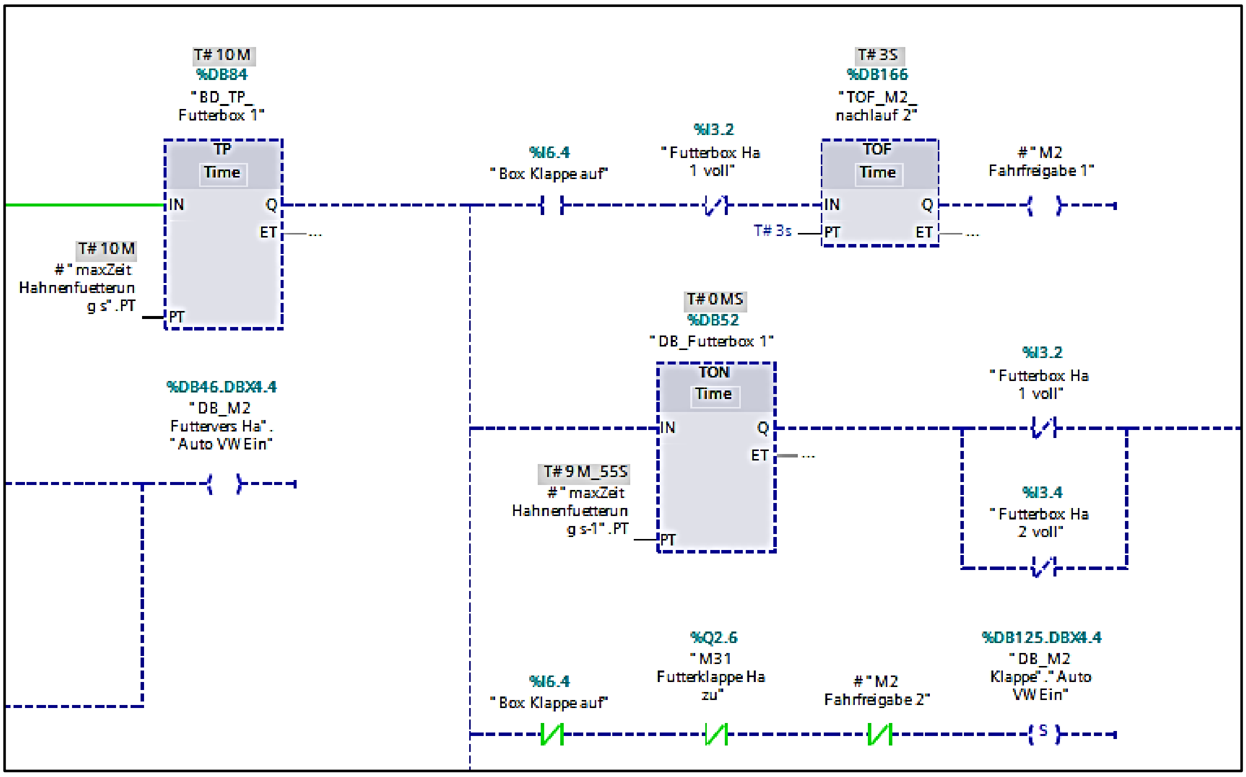


Fig. 38: Software program - feeding system, Source: Own illustration

The software program for the complete broiler breeder management system is very comprehensive and therefore a good programming structure is necessary to create a very consistent working program. The complete program is divided in several subprograms. Each main function of the control system has a separate function block and data block. The main program combines all subprograms and makes it possible to control the henhouse.

[56] Cf. Siemens (Ed.) (2016), Online-Source [14.11.2016]

TIA Portal V13 lends itself admirably to create the program for the CPU for this project. It can be used to test all the functions and it makes it easy to find mistakes in the program. A very useful feature is to test every function block separately and thus saving time because the error can be found faster.

Fig. 39 illustrates a part of the SMS subprogram. If the system recognizes a failure, it sends a message to the operator. In this part, all error messages have been prepared.

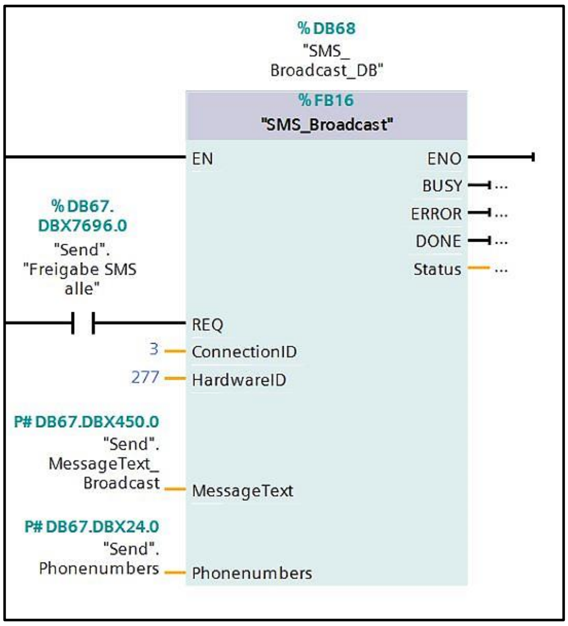


Fig. 39: Development of the SMS Subprogram, Source: Own illustration

For each electrical motor, a separate data block is used. Fig. 40 illustrates the structure of the different data blocks.

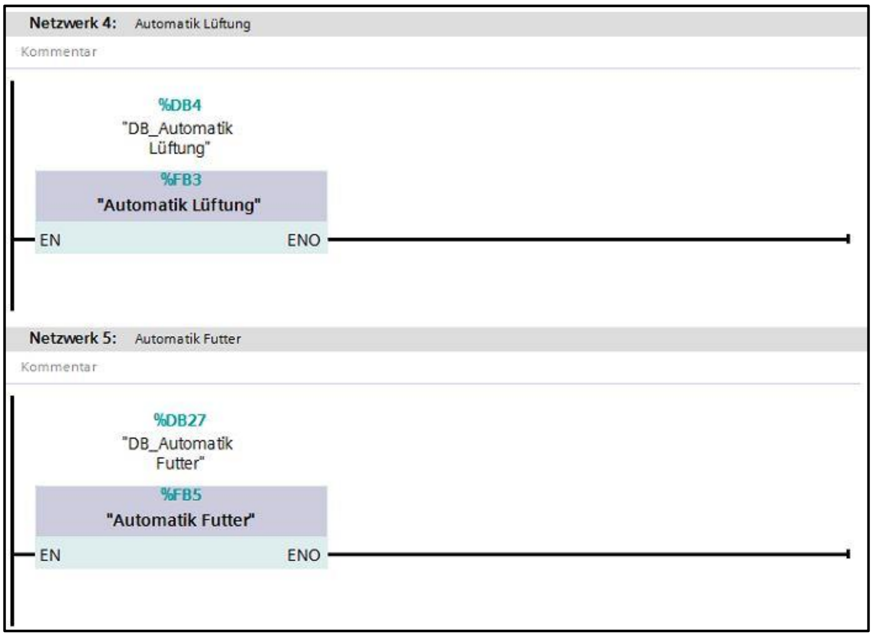


Fig. 40: Overview of the electrical driver motors, Source: Own illustration

5.3.2 Graphical user interface

TIA Portal V13 offers the functionality to create a graphical user interface as shown in Fig. 41. This screenshot represents the development of the user interface for the climate control. Each sub control system has its own graphical user interface. The user has the possibility to choose between the different graphical user interfaces.

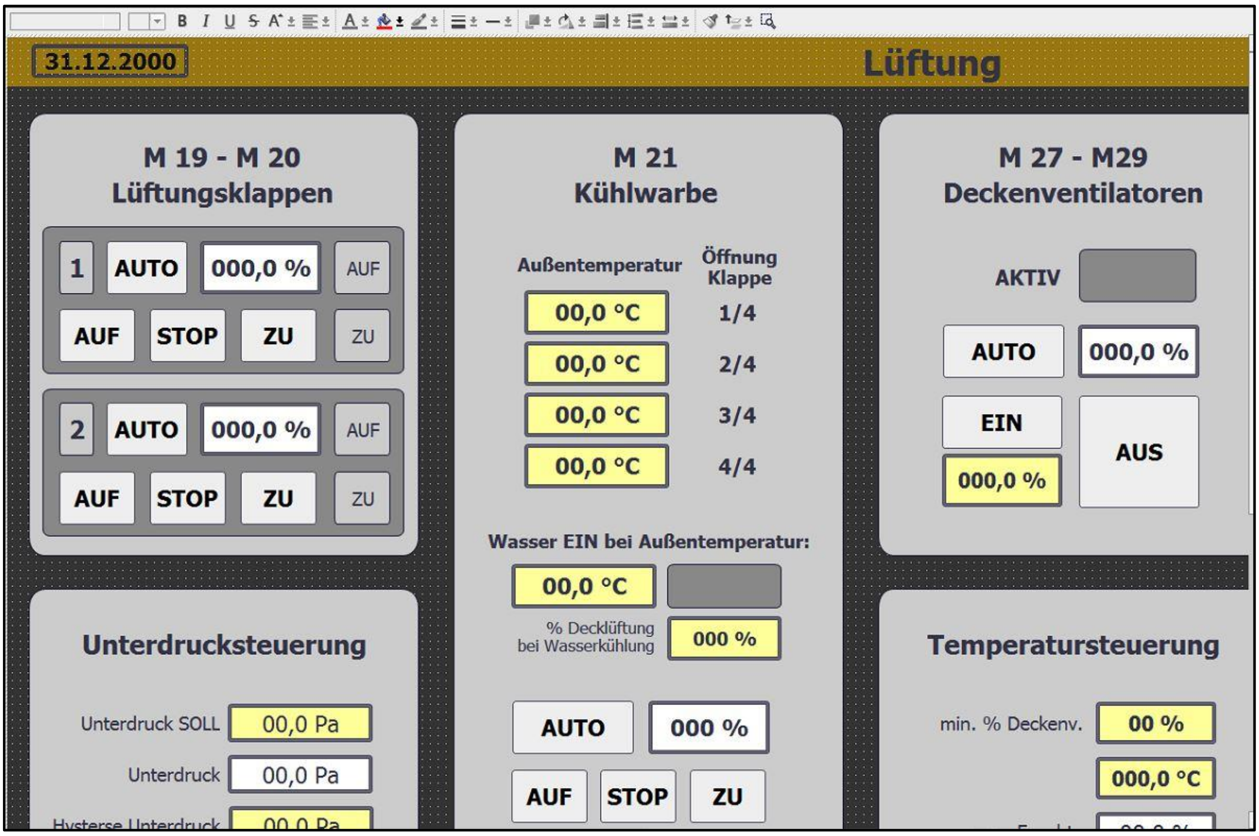


Fig. 41: Designing of the user interface, Source: Own illustration

The connection between the user and the central processing unit is the graphical user interface. It gives important feedback to the user and the user can operate the whole syste with it. Therefore, it is very important to provide a clear structure on this interface. Chapter 5.4 shows the interfaces of all the submenus and describes the functions of them.

The user interface "*Overview*" shows the most important information of the henhouse. The main use for this interface is to give a perfect overview over the system. It summarizes the most important information of the poultry house and should be used as the standard menu selection. Fig. 42 illustrates the menu "*Overview*" with the buttons for the other submenus on the right side.

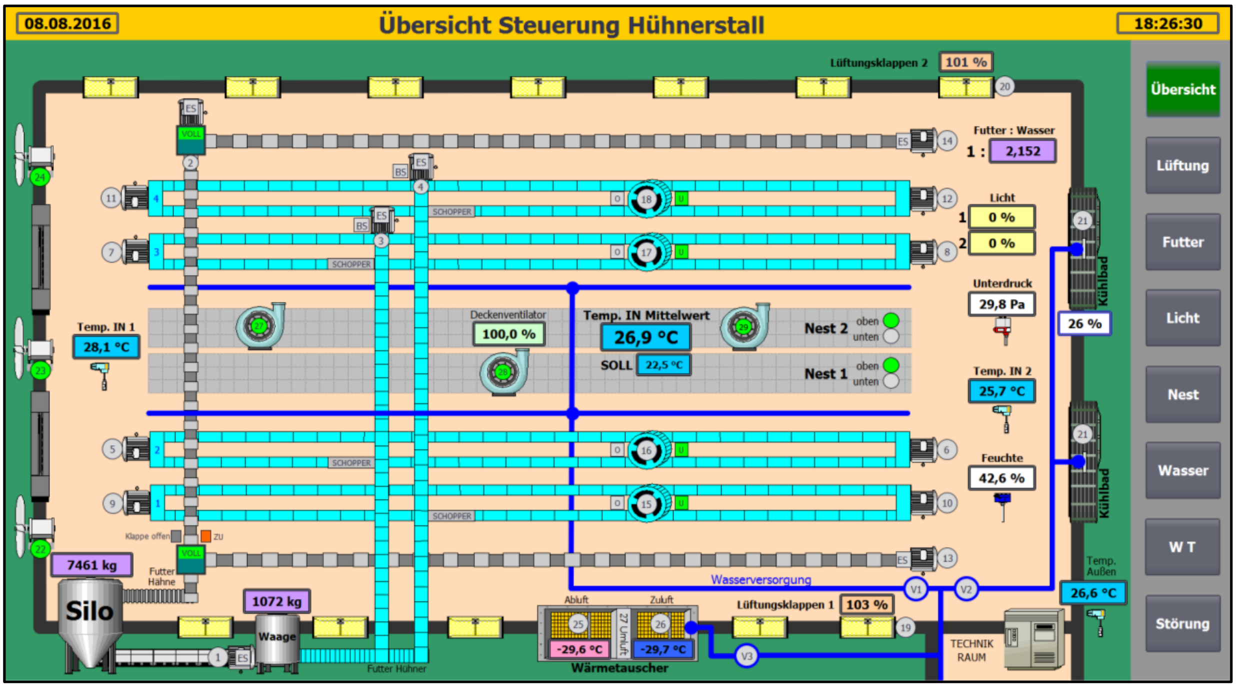


Fig. 42: User interface - Overview, Source: Own illustration

It is not possible to alter any settings or change any values of the control system with this user interface. This view only shows information. However, a submenu for each function of the broiler breeder management system exists. If the user wants to change settings of the control system, it is possible for the operator of this system to choose the according menu selection. Each menu item can be selected by simply touching the screen with a finger. The self-explaining design of the user interface is developed together with Mr. Taucher, the operator of this system. In each development step, Mr. Taucher gives feedback about the usability of the design. This way, it was possible to generate an individual user interface for the customer, in this case, Mr. Taucher.

5.4 Control systems

5.4.1 Climate control system

The climate control system is one of the most important parts of the broiler breeder management system, as it has a big influence on the welfare of the chickens and roosters. This sophisticated system is significantly different compared to the control system, which exists in the old henhouse ST3. This developed climate control system has a positive effect on the egg laying performance and makes sure, that the poultry animals stay healthy. The farmer is able to save money, because medicine for this large amount of animals is very expensive. Unfortunately, it usually happens very often that chicken farmers have problems with sick chickens. Especially in the winter, when the outdoor temperature is very low, the animals are very vulnerable to diseases.[57]

The climate control system for ST4, the new henhouse, contains several electrical devices to generate improved climate conditions for the poultry animals in the henhouse. An excellent collaboration between following components is necessary for the climate control system:

- Roof ventilators
- Cross-flow ventilators
- Air wall inlets
- Cooling combs
- Heat exchanger

Fig. 43 illustrates the heat exchanger from the interior view. The main part of the heat exchanger is located outside of the building. The distance between the inlet and outlet was recommended from the heat exchanger manufacturing company. This picture shows only the two openings for the heat exchanger.

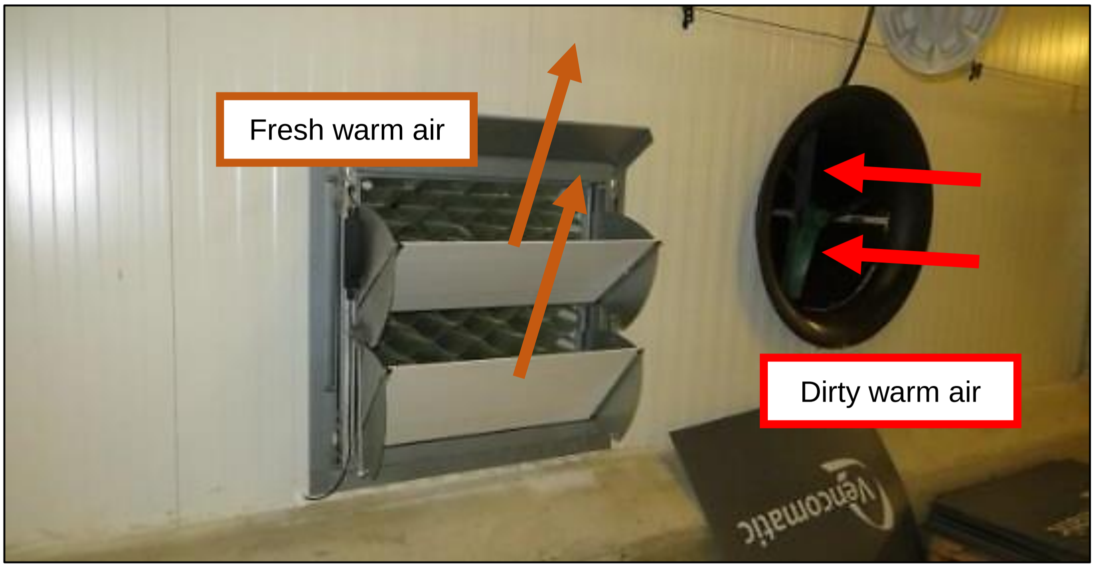


Fig. 43: Heat exchanger - view from inside of the building, Source: Own illustration

[57] Cf. Leeson/Summer (2009), p. 223.

The heat exchanger sucks the dirty air from the inside of the building and transport the polluted air to the outside of the building. At the same time, the heat exchanger blows fresh warm air into the building. This device uses the hot air to warm up the new, fresh air. However, the two types of air streams are never mixed. After that, the warm fresh air will be blown to a wind sail (Fig. 44), which is mounted under the roof. This wind sail transports the fresh air to all places in the henhouse. There are circulating fans, mounted on the left and on the right side of the wind sail, which transport the air in both directions.

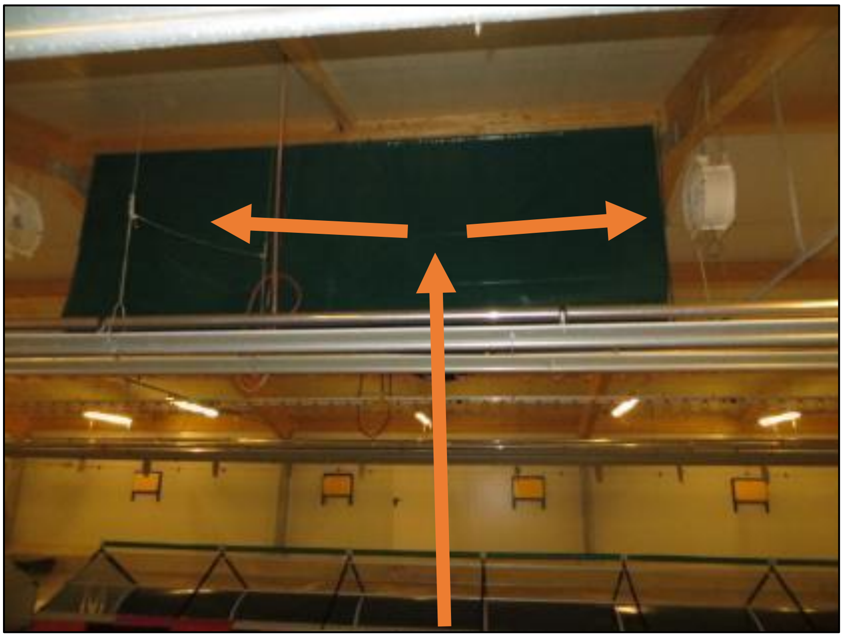


Fig. 44: Wind sail for heat exchanger, Own illustration

Due to the fact, that Austria has four seasons and the temperature changes significantly during the year, the climate control system needs special devices to generate a comfortable climate for the chickens throughout the year. The roof ventilators, the cross-flow ventilators and the air wall inlets are working most of the time, but the other two parts of the climate control system work only for some weeks every year.

The cooling combs are working only in the summertime, when the outdoor temperatures are very high, because it is necessary to additionally cool down the air during this time. On the other hand, the heat exchanger works at low outdoor temperatures. This method helps to prevent diseases of the chickens and roosters.[58]

The combination of these devices will generate a better climate in the new poultry house ST4 compared to the older building ST3. Henhouse ST3 has no heat exchanger and no cooling combs. This makes it more difficult to generate optimum climate conditions for the animals. Excellent climate conditions can improve the egg production of the chickens, ultimately, this brings a higher profit for the farmer.

[58] Cf. Janker (Ed.) (2016), Online-Source [14.11.2016]

There are six big ventilators in the henhouse, three of them are roof ventilators. It is possible to change the power level of the roof ventilator with the CPU by changing the temperature setting. The CPU cannot access the roof ventilator directly, because the frequencies are not the same and they need to be converted. Fig. 45 represents the basic function of the frequency converter. Generally, this converter (Fig. 45) has three blocks:

- Rectifier
- DC filter
- Inverter

At first the frequency converter converts the AC power source into a DC voltage and finally the DC voltage is chopped up into an AC voltage of the requested frequency.[59]

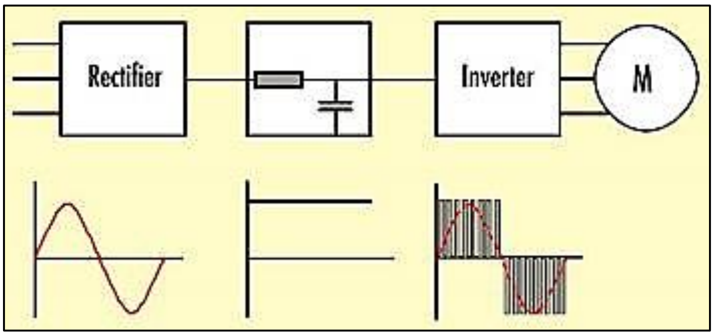


Fig. 45: Function of the frequency converter, Source: Frequencyconverter (Ed.) (2016), Online-Quelle [27.11.2016]

The CPU controls the power level of the roof ventilators, which are accessed by the converters. Fig. 46 illustrates the used electronic components for the henhouse and how they access each other. The frequency converter is electrically controlled by the analog output of the control processing unit and the roof ventilator is accessed by the frequency converter.

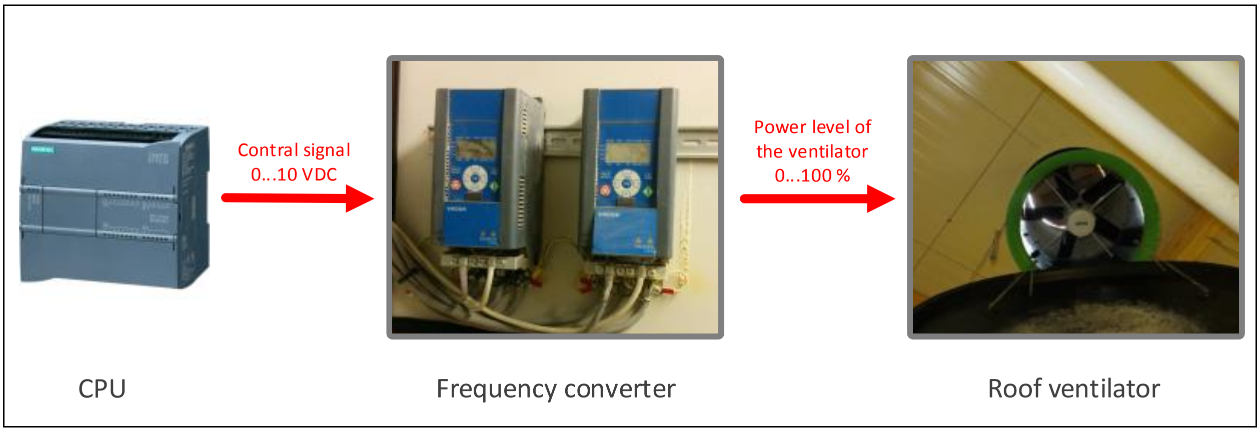


Fig. 46: Control of the roof ventilators, Source: Own illustration

[59] Cf. Plaßmann/Schulz (2009), p. 826.

The roof ventilators are regulated by a PID regulator module (Fig. 47) from the software TIA Portal V13. This module gets the current measured temperature values and controls the power level of these ventilators.[60]

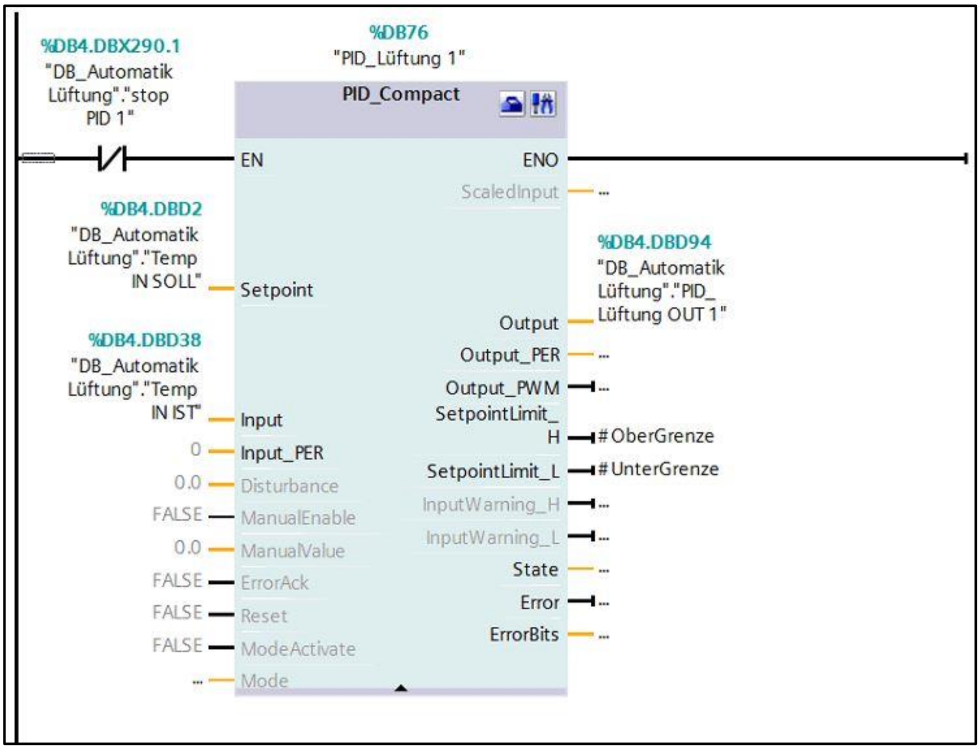


Fig. 47: PID regulator for the roof ventilators, Source: Own illustration

The output value of the PID regulator module is used to regulate the roof ventilators. The regulation of the ventilation system depends on the following measured values:

- Outdoor temperature
- Indoor temperature
- Position of the air wall inlet doors
- Status of the cooling combs
- Status of the heat exchanger
- Humidity

[60] Cf. Siemens (Ed.) (2016), Online-Source [14.11.2016]

The Ziegler-Nichols Method is used to adjust the PID regulator for roof ventilators. This method is a heuristic rule to optimize the three values P, I and D for the PID regulator.

Steps of the Ziegler-Nichols method (closed loop):

- Turn the PID controller into a P controller. Turn off the I term and the D term
- Increase proportional gain from 0 slowly until there are sustained oscillations in the system – look at the output of the controller - increase K_P until the output exhibits sustained oscillations
- Measure the critical period T_{crit} of the sustained oscillations
- Calculate the parameter values (Tab. 2)

	K_P	T_I	T_D
P control	0.5 K_P	∞	0
PI control	0.45 K_P	T_{crit} / 1.2	0
PID control	0.6 K_P	T_{crit} / 2	T_{crit} / 8

Tab. 2: Ziegler-Nichols' closed loop, Source: Lunze (2007), p. 345.

K_P = path gain of the controller

T_I = integrator time constant of the controller

T_D = derivative time constant of the controller[61]

[61] Cf. Lunze (2007), p. 434.

The sub menu “Climate control” from the user interface uses an own data block, which includes all the necessary setting values. Fig 48. illustrates the most of them.

MenueLueftung	Bool	0.0	false	☑	☑
Temp IN SOLL	Real	2.0	20.5	☑	☑
Hysterese Temp.	Real	6.0	1.0	☑	☑
DeltaPlus T	Real	10.0	0.0	☑	☑
DeltaMinus T	Real	14.0	0.0	☑	☑
DeckenventilatorProz_...	Real	18.0	0.0	☑	☑
DeckenventilatorProz_...	Real	22.0	0.0	☑	☑
LuftklappeProz 1	Real	26.0	0.0	☑	☑
LuftklappeProz 2	Real	30.0	0.0	☑	☑
KuehlklappeProz	Real	34.0	0.0	☑	☑
Temp IN IST	Real	38.0	0.0	☑	☑
TempBeide	Real	42.0	0.0	☑	☑
TempIN Diff 1	Real	46.0	0.0	☑	☑
TempIN Diff 2	Real	50.0	0.0	☑	☑
TempSensorDEF	Bool	54.0	false	☑	☑
AlarmgrenzeMAX	Real	56.0	25.5	☑	☑
AlarmgrenzeMIN	Real	60.0	18.5	☑	☑
KW 0.25	Real	64.0	20.0	☑	☑
KW 0.50	Real	68.0	22.0	☑	☑
KW 0.75	Real	72.0	25.0	☑	☑
KW 1.00	Real	76.0	28.0	☑	☑

Fig. 48: Data block ventilation system, Source Own illustration

Some values of them are fixed, but most of them can be adjusted by the operator of the system. That means, the operator can set the minimum and maximum temperature alarm level and many other values.

An experienced operator knows how to produce good adjustments to the control system, this improves the overall performance of the system significantly.

The user interface “Ventilation system” as shown in Fig. 49 is the first submenu on the main user interface. In this menu, the operator has the opportunity to change all of the relevant settings and values of the ventilation system. This menu is separated into seven parts:

- Air wall inlets
- Negative pressure ventilation system
- Cooling combs
- Roof ventilators
- Temperature control system
- Temperature indicator
- Cross-flow ventilators

The user has the possibility to run each component of the climate control system in automatic mode or in manual mode. The automatic mode controls the chosen component and changes the control values automatically. The air wall inlets can be controlled between 0 and 100 %. There are two electrical motors for all of the air wall inlets. One motor is responsible for the left side and the other one for the right side of the building.

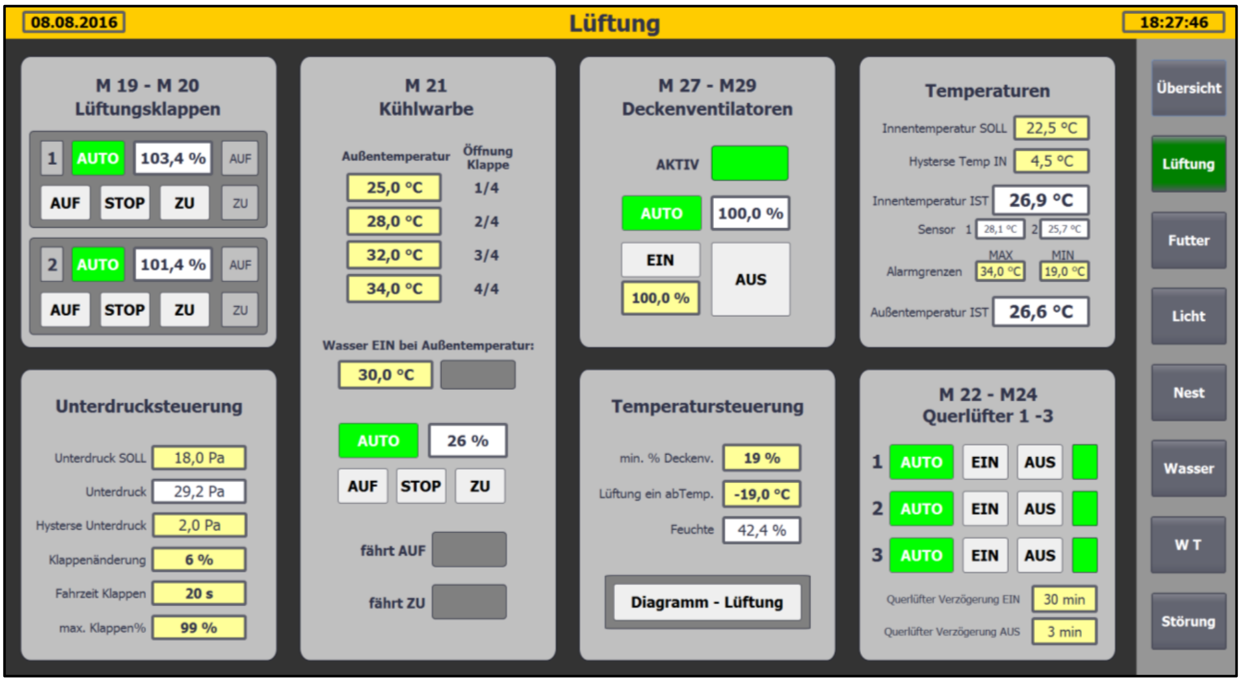


Fig. 49: User interface - Ventilation system, Source: Own illustration

The cooling combs have ventilation dampers and the operator can set the value of temperature, where the dampers have to open. The user can also adjust the starting temperature for the water supply, which provides the cooling combs with water.

Following flow chart (Fig. 50) illustrates the basic function of the climate control system:

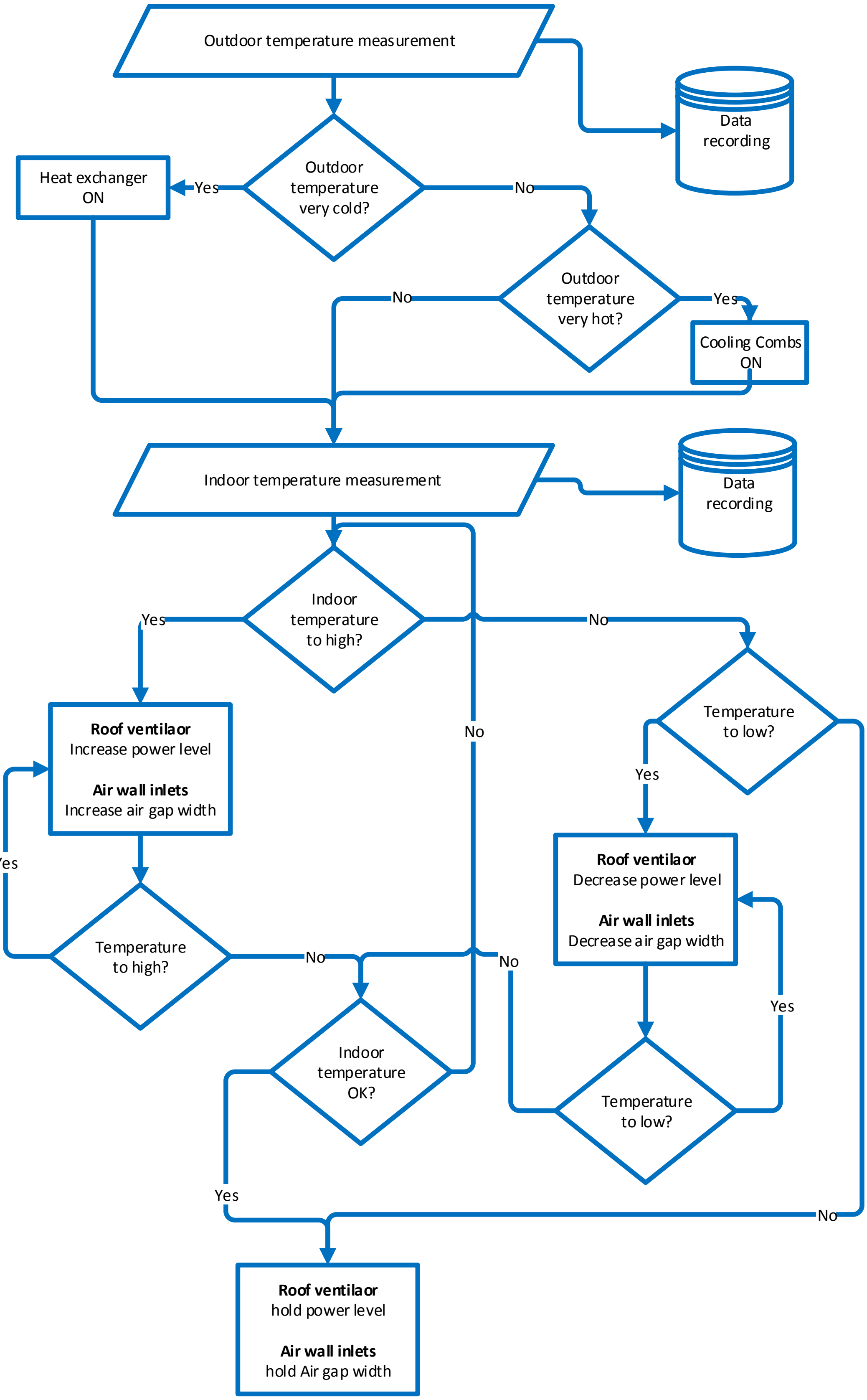


Fig. 50: Flow chart climate control system, Source: Own illustration

The user interface provides a separate submenu for the heat exchanger. It is possible to change all settings of the heat exchanger in this menu. Fig. 51 represents this user interface, but at this time, the heat exchanger is not running. Basically, this device controls one big input ventilator and one big output ventilator. The power level of both ventilators can be adjusted manually by the operator.

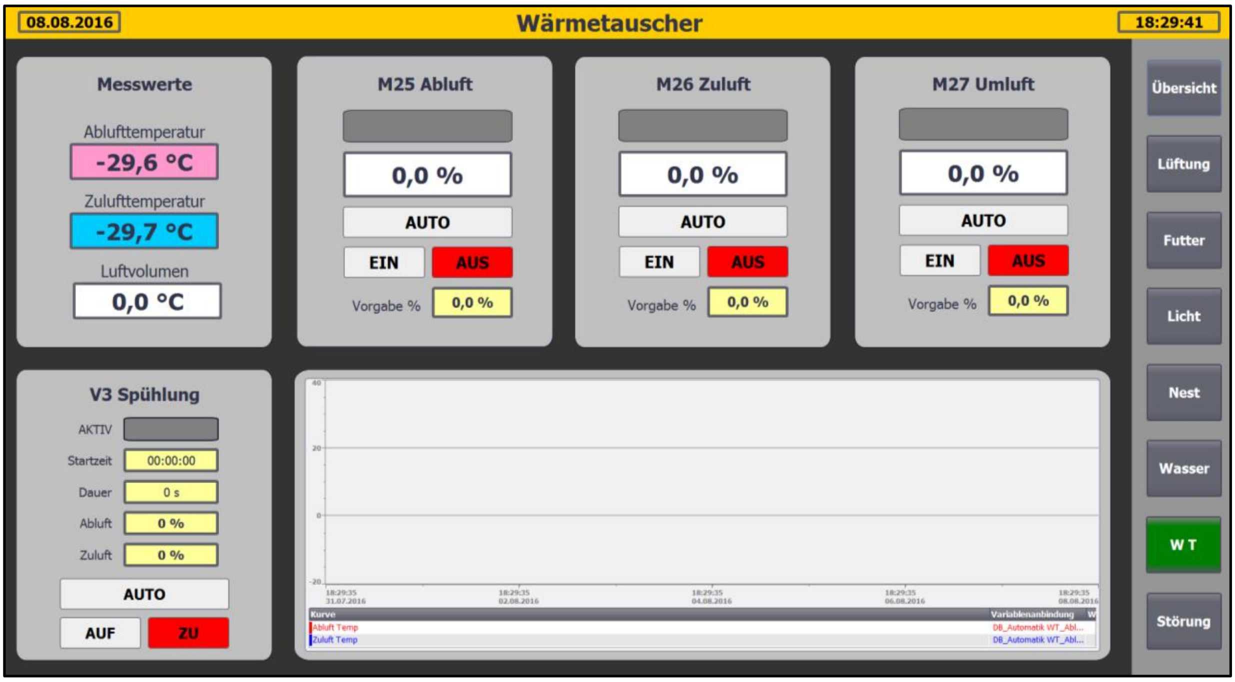


Fig. 51: Submenu heat exchanger, Own illustration

If the operator uses the automatic mode, the control system of the heat exchanger tries to regulate the temperature to the desired temperature value. However, this control system also considers the power level of the roof ventilators. The recirculation fans are also a parts of the heat exchanger and they are mounted directly under the roof near the wind sail. The climate control system has the task of controlling these recirculation fans, which spread the fresh warm air in the building.

5.4.2 Feeding control system

There are two different feeding systems for the chickens and roosters, because they do not eat from the same feeding line. Fig. 52 illustrates two silos with different holding capacity. Silo 1, on the left side, is the main feeding silo, which stores all the feed for the poultry animals in the henhouse. It is not possible to measure the weight of the silo, because there is no scale. On the other hand, silo 2, which is on the right side, is mounted on load cells, which can measure the weight of the feed contained in the silo.

Fig. 52: Feeding silo, Source: Own illustration

The food for the roosters will be transported directly from silo 1 to two feeding boxes in the henhouse. These boxes are mounted on scales and they are going to send a signal to the CPU if they are full. These two feeding boxes provide the feeding lines for the roosters with fodder.

The chickens get their feed from silo 2, which is controlled by the feeding control system. An electric motor transports the feed from the big silo 1 to the smaller silo 2. Furthermore, a second feeding drive motor transports the feed from silo 2 to the feeding lines from the chickens. Fig. 53 illustrates one of the feeding drive motors, which transports the feed from the smaller silo to the feeding lines in the henhouse.

Fig. 53: Feeding drive motor, Source: Own illustration

Following flow chart (Fig. 54) illustrates the feeding process of the feeding system:

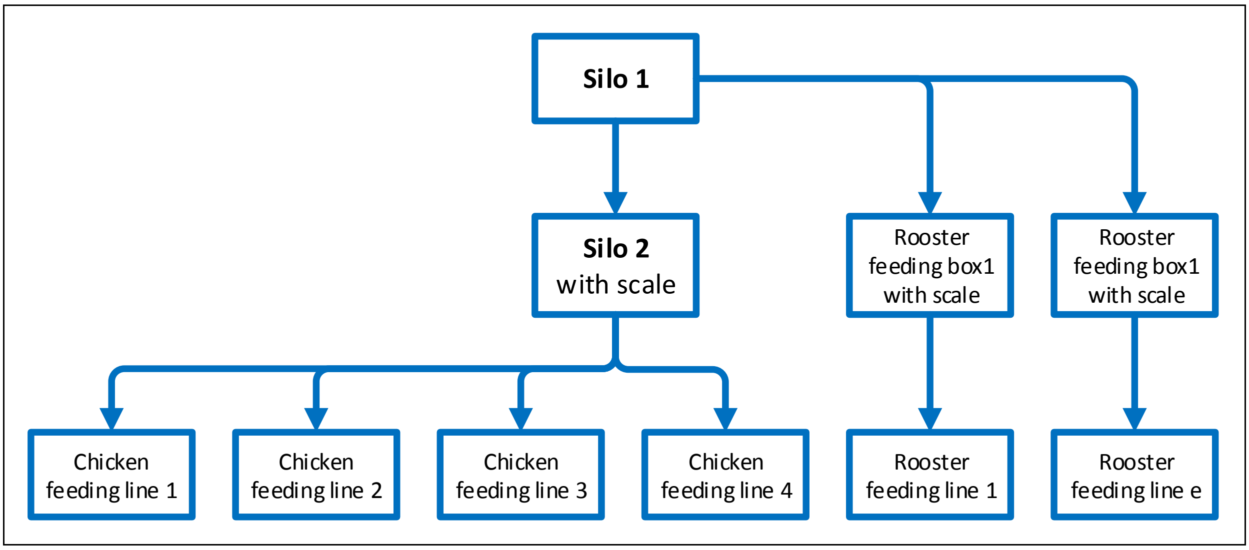


Fig. 54: Flow chart - feeding process, Source: Own illustration

The feeding control system for the roosters is very simple, because there are only two big feeding boxes in the henhouse. Each one of them provides only one feeding line with fodder. This feeding line includes a feeding chain, which is driven by an electric motor (Fig. 55). It is not possible to regulate the power level of this motor. This motor is running as long as fodder is in the fodder box.[62]

Fig. 55: Feeding line for the roosters, Source: Own illustration

[62] Cf. Janker (Ed.) (2016), Online-Source [14.11.2016]

Fig. 56 shows the sophisticated user interface “Feeding control system”, which controls the feeding system for the roosters and the chickens. The feeding control system for the chickens is more complex, because there is much more feed which the feeding lines have to bring to the chickens. The feeding time is early in the morning and the operator has the possibility to set 13 different feeding times. Generally, the first feeding time is at 3 o’clock in the morning and the time difference between each feeding cycle is 30 minutes. The control system records the feeding consumption for every day separately. It also records the complete food consumption.

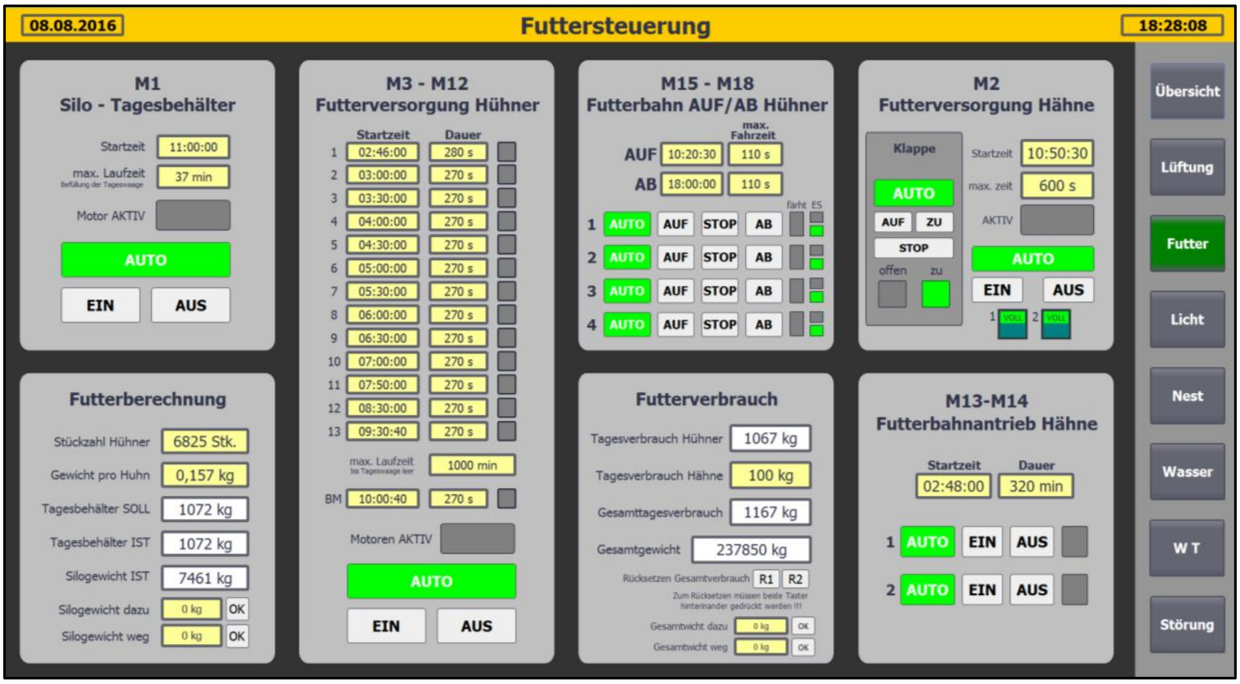


Fig. 56: User interface - Feeding control system, Source: Own illustration

The development of the feeding control user interface was very time-consuming, because there is a lot of information on the user interface and the operator has several setting options to optimize the feeding process. This makes it possible to create a faster and better feeding system compared to the feeding system from ST3.

5.4.3 Lighting control system

The lighting control system, as shown in Fig. 57, is very simple. In the automatic mode, the operator can set the lighting power level for lighting row one and for lighting row two. Additionally, to the setting options, this sub user menu offers a diagram which illustrates the power level of the light.

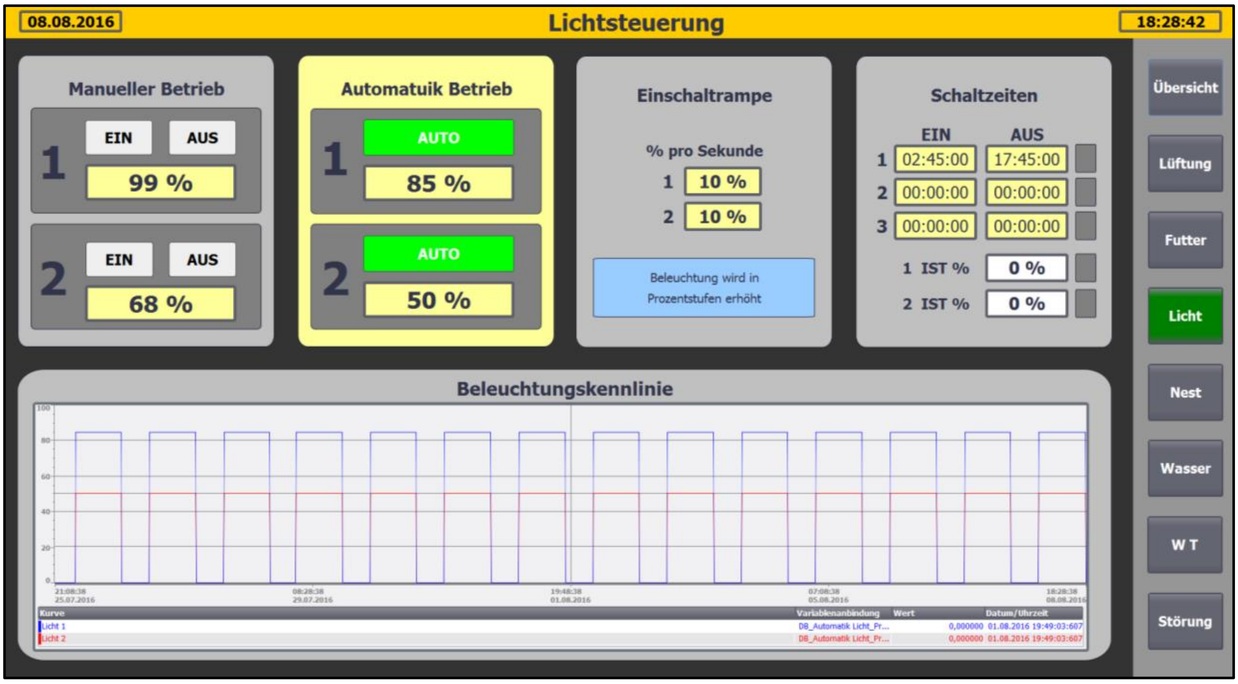


Fig. 57: User interface - Light control system, Source: Own illustration

As shown in Fig. 56, the power level from lighting line one is not the same as the power level from lighting line two. The reason for that is the position of the egg laying boxes. These boxes are located in the middle row of the henhouse and the aim is that the chickens lay their eggs in this boxes. The operator can influence the egg laying position of the chickens. For instance, the first lighting line has 80% power level and the second lighting line has only 50 % power level. The chickens prefer to lay their eggs at darker places, therefore, the lighting line near the egg laying boxes is darker.

5.4.4 Egg collecting System

Compared to the egg collection system of henhouse ST3, the new one offers some special functions. Before the egg conveyor starts to transport the eggs from the egg boxes to the egg sorting room, the floor of the egg boxes moves up so that the eggs con roll on the egg conveyor. This process is dangerous for the chickens, because some of the chickens do not leave the egg box when the floor moves up and the moving floor squeezes the chickens and hurt them.

The new egg collecting system of ST4 has a safety function to prevent this from happening. The floor of the egg box starts moving up and after some seconds it moves down. After that, all of the chickens leave the egg box because they are scared and the floor starts moving up again. This method works perfectly, because after four months testing, no chicken was squeezed. Fig. 58 illustrates the user interface “Egg collecting system”.

Fig. 58: User interface - Egg collecting system, Source: Own illustration

5.4.5 Water control system

Fig. 59 illustrates the drinking water supply line for the roosters and chickens, which includes a lot of water drinking cups. The water control system controls the water supply with magnetic valves, which can open and close the water supply pipe. A water mass flow meter is used to measure the used water.

Fig. 59: Drinking water supply line, Source: Own illustration

The sub menu “Water control system” (Fig. 60) was developed to control the water supply for the drinking water and also for the cooling combs. However, only one water mass flow meter is used for the drinking water supply. This mass flow meter sends one voltage impulse for every liter water to the digital input channel of the CPU. The drinking water consumption is recorded and if the poultry animals are not drinking enough, the control system sends an alarm message to the operator.

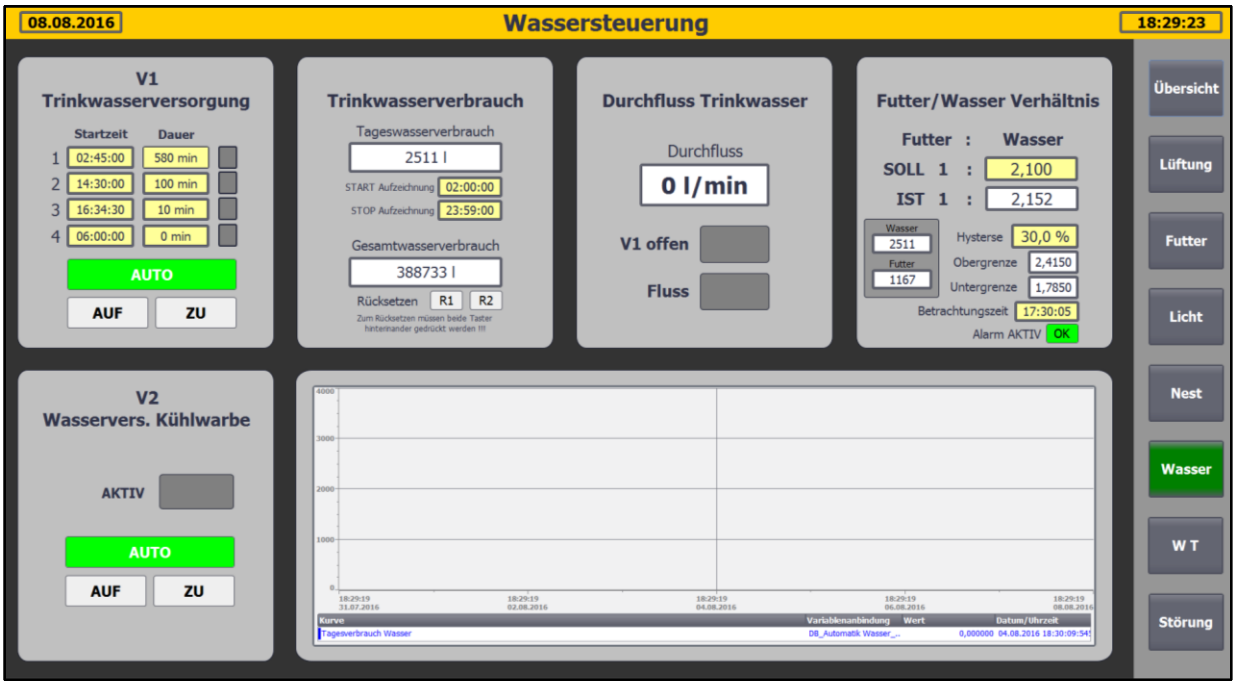


Fig. 60: User interface - Water control system, Source: Own illustration

5.5 Safety features

The new control system of the poultry house ST4 provides several safety features, which guarantee a secure life for all animals in the henhouse. The control system informs the operator via SMS if there are any errors with the electronic components in the building.

5.5.1 Error notification

The user interface has a submenu which is responsible for the error messages. If there is a problem with the control system, the GSM module, which is connected to the CPU, sends an alarm SMS to the mobile phone of the operator. It is possible to add an additional cell number to the system and the user of the system can decide which numbers are activated. Additionally, each error is displayed on the user interface. There are two windows, the first one shows the actual errors and the second one displays the older errors that have already been resolved. Fig. 61 represents this "*Error*" submenu.

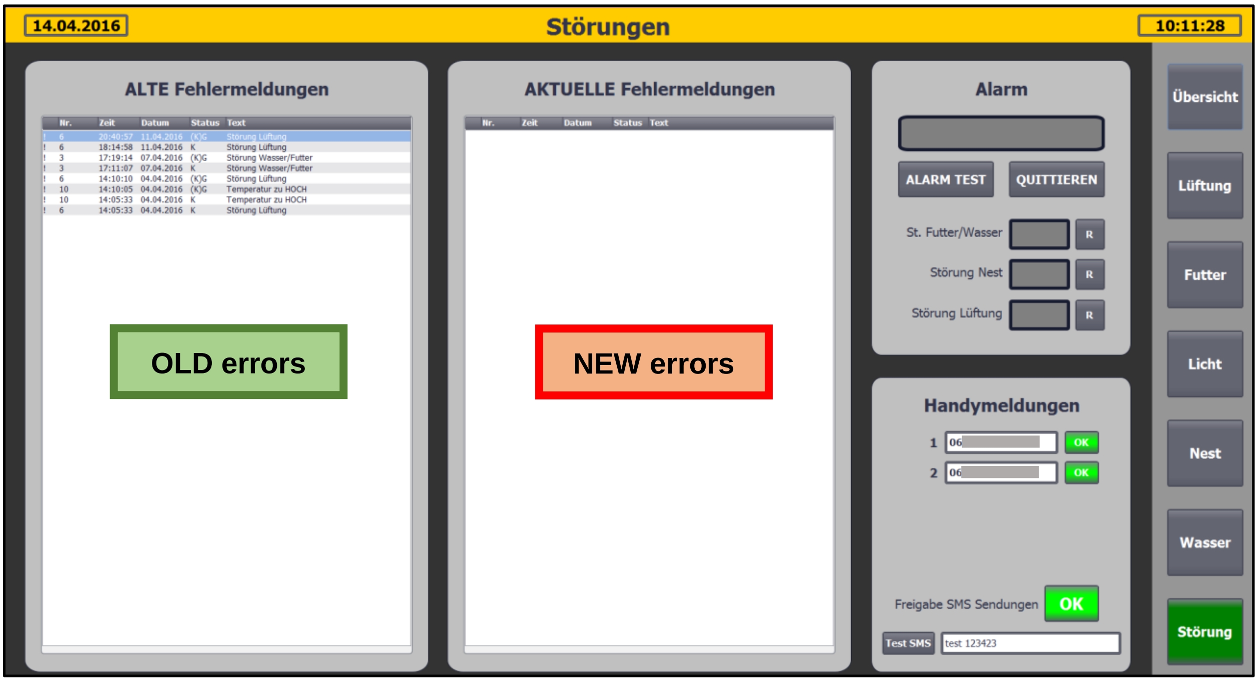


Fig. 61: Error message menu, Source: Own illustration

Each error is on the main user interface, the "Overview". A red flashing light showing a short error information signals an error on the menu "Overview". The operator can also use the remote control function and has the possibility to check the error on his smart phone.

However, after each alarm, the operator has to check the error. It is also necessary to quit the error manually, but this is makes sense when the error is actually resolved. The error window helps the operator to find the error, because the error text on the user interface describes the occurred error exactly. The operator can quit the different subsystems separately.

The complete error message list is defined in the software program for the control processing unit. Several error messages are illustrated on Fig. 62The messages shown are only for the error user interface, because the description is very short and gives the operator the main information about the failure. The SMS message that is sent is more detailed than the represented messages in Fig. 53.[63]

Bitmeldungen

ID	Meldetext	Meldeklasse	Triggervariable	Trigge..	Triggeradresse
1	Störung Deckenventilator	Errors	Deckenventilator	9	%DB1.DBX10.1
7	Störung Nest	Errors	AUTO Alarm	14	%DB55.DBX0.6
5	Ein Innenteperaturfühler ist defekt	Errors	AUTO Lüftung 2	8	%DB4.DBX54.0
6	Störung Lüftung	Errors	AUTO Alarm	13	%DB55.DBX0.5
3	Störung Wasser/Futter	Errors	AUTO Alarm	12	%DB55.DBX0.4
10	Temperatur zu HOCH	Errors	AUTO Lüftung 1	8	%DB4.DBX84.0
11	Temperatur zu NIEDRIG	Errors	AUTO Lüftung 1	9	%DB4.DBX84.1
4	M2 Futterversorgung Hähne Zeitüberschreitung	Errors	AUTO Futter 1	13	%DB27.DBX10.5
12	M1 Silo-Tageswaage Zeitüberschreitung	Errors	AUTO Futter 1	12	%DB27.DBX10.4
13	M28 Nest 1 Zeitüberschreitung	Errors	AUTO Nest 1	8	%DB30.DBX100.0
14	M29 Nest 2 Zeitüberschreitung	Errors	AUTO Nest 1	9	%DB30.DBX100.1
17	Futterbahn Hühner hinauffahren Zeitüberschreitung	Errors	AUTO Futter 1	8	%DB27.DBX10.0
18	Futterbahn Hühner Hinuntefahren Zeitüberschreitung	Errors	AUTO Futter 1	9	%DB27.DBX10.1
21	Störung Test	Errors	AUTO Alarm	15	%DB55.DBX0.7
22	Kein Wasserverbrauch (20Minuten)	Errors	AUTO Wasser 1	10	%DB29.DBX166.2
23	Wasseverhältnis Fehler	Errors	AUTO Wasser 1	11	%DB29.DBX166.3
24	Fehler Schopper	Errors	AUTO Futter 2	13	%DB27.DBX222.5
25	M3-M4 Futterversorgung Hühner Zeitüberschreitung	Errors	AUTO Futter 3	8	%DB27.DBX174.0
2	Wärmetauscher Alarm	Errors	WT	8	%DB55.DBX14.0
8	M1 ES-Störung	Errors	AUTO Futter 4	8	%DB27.DBX705.0
9	M2 ES-Störung	Errors	AUTO Futter 4	9	%DB27.DBX705.1
15	M3 ES-Störung	Errors	AUTO Futter 4	10	%DB27.DBX705.2
16	M4 ES-Störung	Errors	AUTO Futter 4	11	%DB27.DBX705.3
19	Störung Futterversorgung	Errors	AUTO Futter 5	9	%DB27.DBX156.1
<Hinzufügen>					

Fig. 62: Error messages, Source: Own illustration

There are a few errors, which are very critical and can damage devices in the henhouse. If the control system realizes one of these errors, it will stop the concerned sub control system and the error has to be remedied before this sub control system can start again. For instance, if an electric feeding drive motor stops working, the GPS module sends an error message to the operator and the feeding control system will be stopped immediately. All the other sub control systems, like the climate control system, keep working. After removal of the fault, the operator can quit the error and the feeding control system starts working again.

63 Cf. Siemens (Ed.) (2016), Online-Source [14.11.2016]

5.5.2 Emergency power supply

Mr. Taucher has a lot of other chicken farmers in his neighborhood. They support each other if somebody has problems or need help. If Mr. Taucher is on vacation with his family and nobody is at home, there is always a person which is not far away. They will be alarmed from the control system if the there is a problem in the henhouse. The cellphone numbers of these helpful neighbors are saved in the control system and the operator can activate these numbers. That means at all times, somebody is not far away from the chicken farm.

The atomized broiler breeder management system has an uninterruptible power supply[64] (UPS) if there is a breakdown of current. The most dangerous situation for the chickens and roosters is a power blackout in the summer when the temperatures are very high. High outdoor temperatures also lead to higher indoor temperatures, if the ventilation system stops and the air wall inlets are closed.[65]

However, if there is a real electricity failure, the UPS will be activated and this supports the most important devices with electrical energy. If this situation happens, the following appliances will be provided with energy:

- Central processing unit inclusive GPS module
- Computer with user interface
- Air wall inlets

[64] UPS = Uninterruptible Power Supply

[65] Cf. Baehr (2005), pp. 30-31.

The UPS supports only these three parts (Fig. 63) of the henhouse with electrical energy, because it has not enough power to access the ventilation system or the feeding system. The air wall inlets are essential. They have to be open to let fresh air into the henhouse. If there is a current breakdown, the control system opens all air wall inlets.

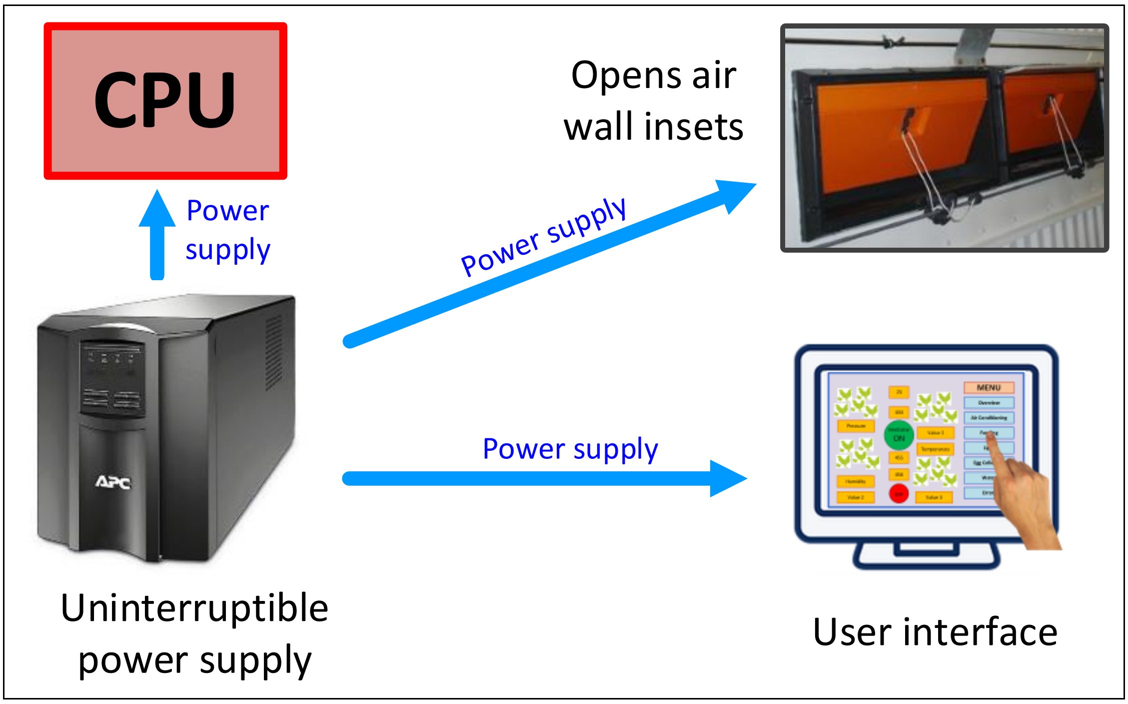


Fig. 63: Uninterruptible power supply, Source: Own illustration

Additionally, the uninterruptible power supply also provides the central processing unit and the computer with the user interface with electrical power. The CPU with the GPS module is necessary to send alarm messages to the operator or to responsible persons.

The operator has the possibility to check the errors with the remote control system. Therefore, the computer with the user interface is also important in case of a power blackout. The CPU and the computer do not need a lot of electrical energy. The electrical motors, which have the task to open the air wall inlets, need the most electrical energy from the UPS. The used uninterruptible power supply has enough power to open all air wall inlets and to support the other two devices for around 5 hours.[66]

Water is also important for the animals in the henhouse, but it is not necessary to activate the water pump for this short time, because they have enough water for some hours.

[66] Cf. APC (Ed.) (2016), Online-Source [29.11.2016]

The emergency power generating set with a tractor universal joint shaft is also a part of the safety equipment for the henhouse. This special device can produce electrical energy that can be used to control the poultry house. However, a tractor is necessary to drive the joint shaft of the power generator. Due to the fact that Mr. Taucher has three tractors at home, this type of power generator is perfect for that application. If the electricity failure takes a longer time, this emergency power generating set (Fig. 63) will be used to generate the electricity for the poultry house.

The biggest difference between this power generating set and the UPS is that this emergency power generating set has much more power and can generate more electric energy for the henhouse. With this power generator, it is also possible to power following components:

- cross-flow ventilators
- Air wall inlets
- Drinking water supply
- Computer with user interface
- Central processing unit

However, it is not feasible to provide the complete henhouse with electrical energy. Therefore, the five most important devices are selected and shown in Fig. 64.

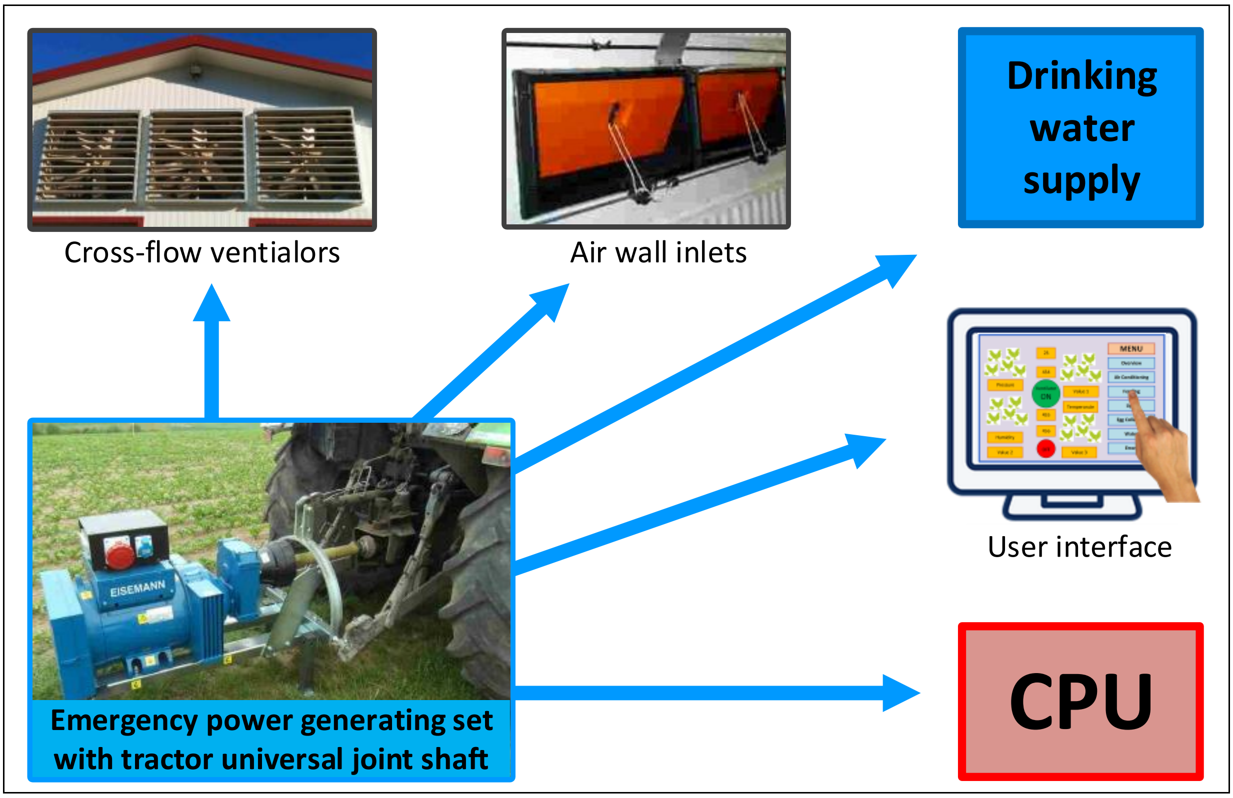


Fig. 64: Emergency power generating set with tractor universal joint shaft, Source: Own illustration

6 IMPLEMENTATION OF THE CONTROL SYSTEM

The electrical distribution box, which is responsible for the control of the whole poultry house, is located in the controller room. The implementation process includes the conjunction of the CPU and the other electronic parts in the distribution box.

6.1 Electrical distribution box

After testing the finished software for the henhouse control system in the development labor, the CPU and the additional modules are implemented in the electrical distribution box as illustrated in Fig. 65. However, that is not the final position of the computer with the user interface. This device will be mounted in a separate place in the controller room. The distribution box includes a lot of electronic components like relays, miniature circuit breakers, power supplies and many other electronic parts.

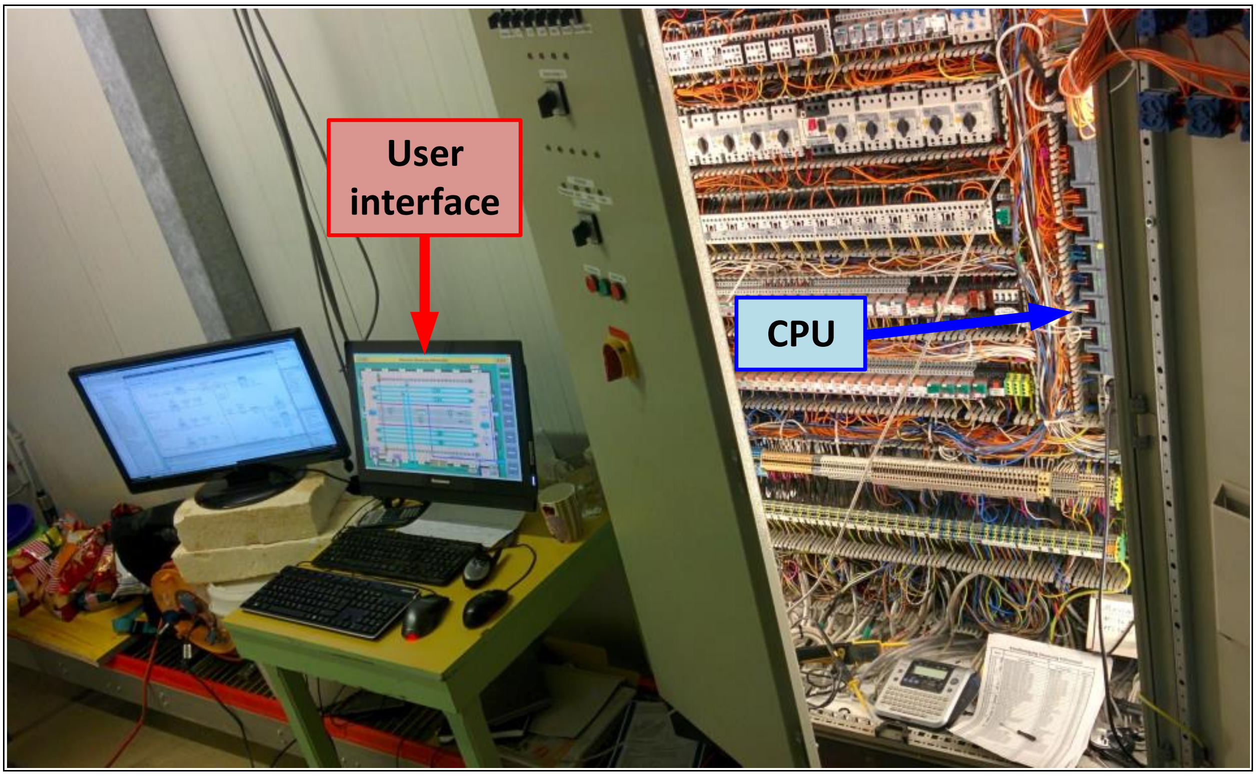


Fig. 65: Implementation of the control system, Source: Own illustration

After the final implementation of the electrical parts, a lot of functional tests are made to check the functionality of the control system. Furthermore, it was necessary to do a lot of software settings, because it is impossible to do all of the software settings with only the test setup in the development labor.

Fig. 66 shows the installed CPU with the GSM module, which is responsible for the alarm messages. As can be seen, all additional used modules are connected to the CPU. This control unit saves a lot of space, compared to the very big electrical distribution box. That is another big advantage of this control system.

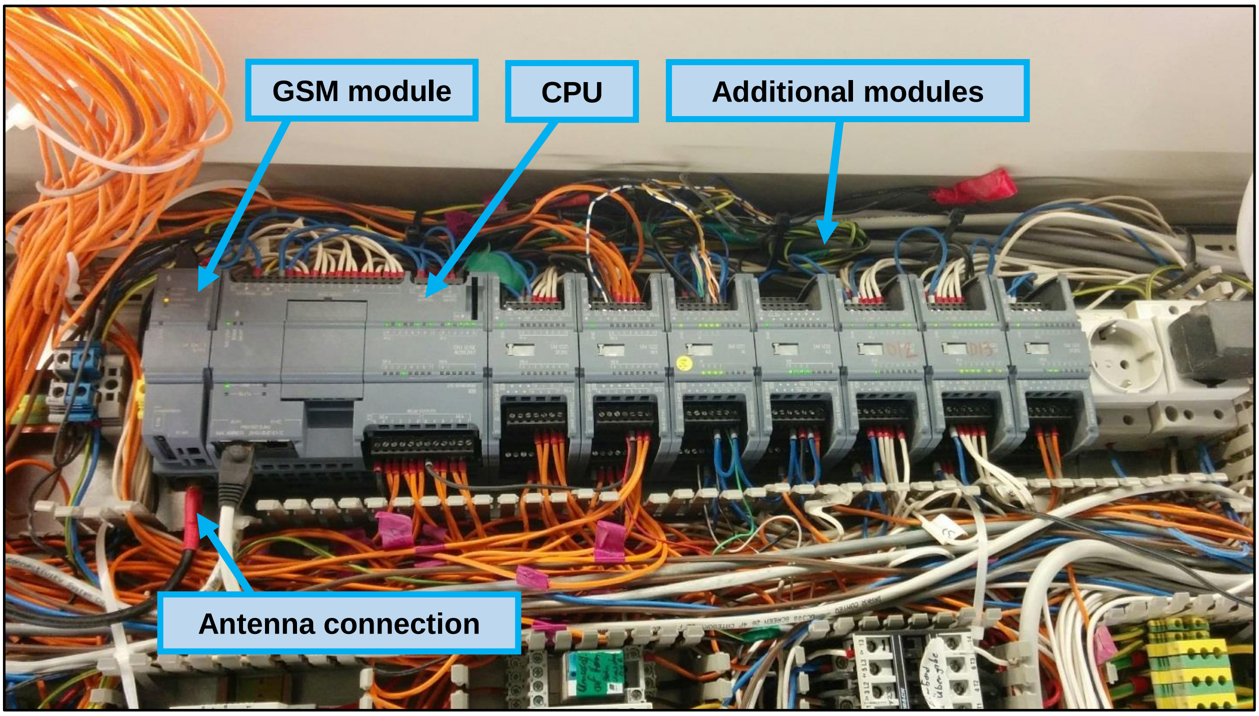


Fig. 66: CPU + GSM module, Source: Own illustration

The GSM module needs an antenna (Fig. 67) to communicate with the mobile network. A special antenna from the company Siemens is used to generate a safety connection to operator. The antenna is mounted on the top of the roof from the henhouse to get a good GSM reception. The antenna is waterproof and shockproof, which prevents the antenna from failing at this raw ambient conditions.[67]

Fig. 67: Antenna for the GMS system, Source: Siemens (Ed.) (2016), Online-Source [14.11.2016]

[67] Cf. Siemens (Ed.) (2016), Online-Quelle [14.11.2016]

6.2 Measurement recordings

All measured values can be seen on the user interface in form of digital numbers. Measured data is illustrated on the interface in the form of online diagrams. This information is important for the operator to see the status of the climate and living conditions in the henhouse.

Additionally, the control system records several measured values. Following physical quantities have been recorded:

- Indoor temperature
- Outdoor temperature
- Humidity
- Water consumption
- Light power level for light row 1
- Light power level for light row 2
- Food consumption

For the first four test months of the control system, these mentioned measurement values have been recorded, because they are the most important. However, in the future, there are more values measured and shown, like the input and output temperature of the heat exchanger.

Fig. 68 represents the recordings of the lighting power level, which can be seen on submenu “Lighting control system” on the user interface. This is only one example, there are several other measured values that can be seen on the user interface.

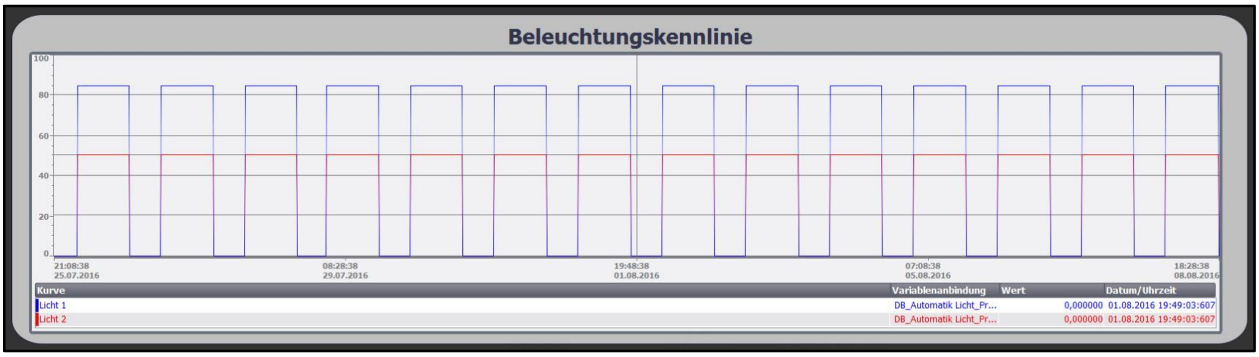


Fig. 68: Recording - light power level, Source: Own illustration

6.3 Remote control

It was not the aim of this thesis to create a remote control for the broiler breeder management building but it is a great additional feature that can be used. The user of the control system has the possibility to control the system from anywhere in the world. The only thing that the operator needs is a working internet connection, a specific remote control program and the connection password.

The remote control software TeamViewer is used to control the henhouse from far away. Unfortunately, this software is not the safest method to control another computer. This software has been chosen because it is free and is also available as an app for the smartphone.

Furthermore, it is very easy to use and it is possible to define a username and a password for the computer with the user interface. That means the operator can use the same password for all remote controls. One of the next aims is to install a better and safer remote control system. Fig. 69 represents the remote control function on a smart phone.

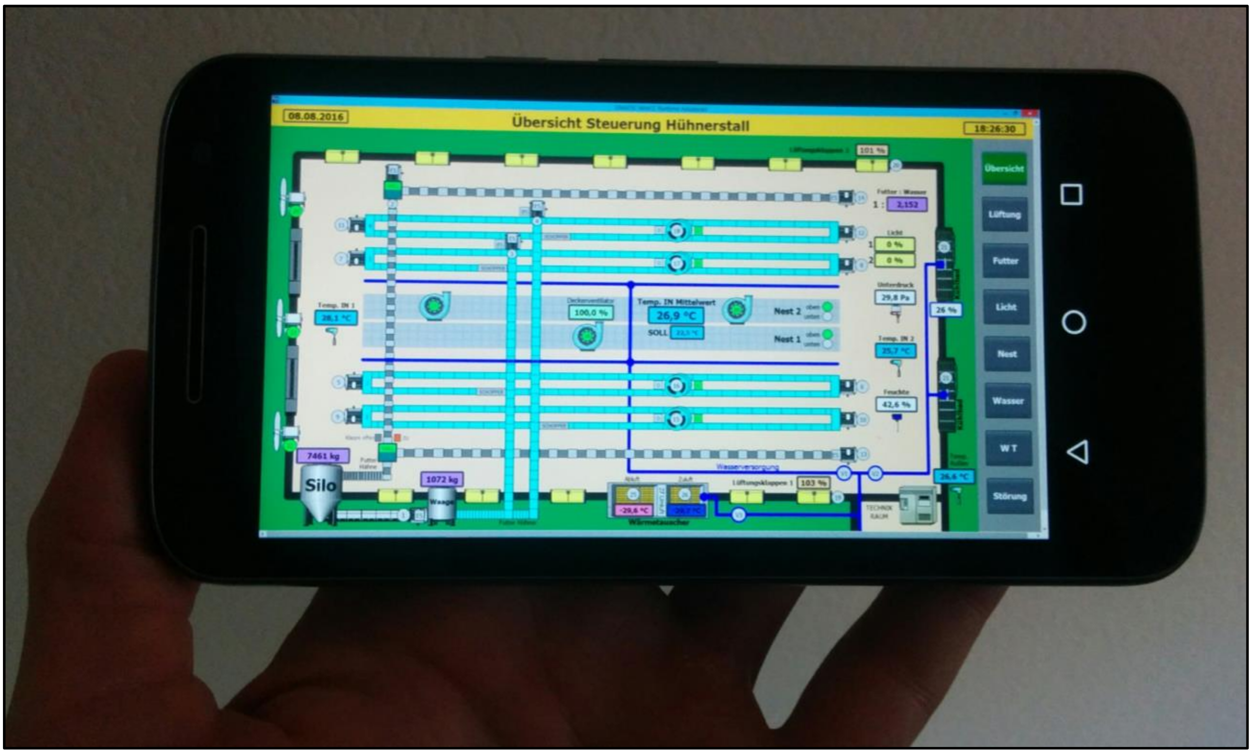


Fig. 69: Remote control via smart phone, Source: Own illustration

6.4 System test

Finally, a system test was made with the broiler breeder management system to check the functions of the system. All the subsystems of the control system were checked for their functionality. These tests were made for the older henhouse ST3 and the new poultry house ST4, because it is important to check both systems in order to compare them. The aim of this project is to generate an improved control system for the ST4 compared to the old one. Therefore, a lot of measurements in both buildings were made and after that, the diagrams of the measurements were used to compare the systems. It should be mentioned that the control system from ST1 and ST2 is worse than the one in ST3. That is the reason why, in this thesis, the new control system for ST4 is compared to the one in ST3.

6.4.1 Climate control system

One of the most important tests is the functionality test of the climate control system. This test is extremely vital because henhouse ST4 has two additional devices compared to ST3. This should lead to a better temperature regulation. The following temperature diagrams show the records for a record time of 300 hours. Fig. 70 illustrates the first temperature record diagram from ST3 in the summer. The blue line represents the recorded outdoor temperature and the red one the indoor temperature for ST3. The desired indoor temperature for the next two diagrams should be 22.5 degrees Celsius. The outdoor temperature has high fluctuations, because the diagram shows around 12.5 days and the temperature in the night is lower than in the day. As can be seen, the real indoor temperature changes a lot and goes up to approximately 27 °C. The climate regulation system from ST3 has no problems with lower temperatures because the bodies of the chickens and roosters emanate a lot of heat and that makes it easier to keep the building warm.

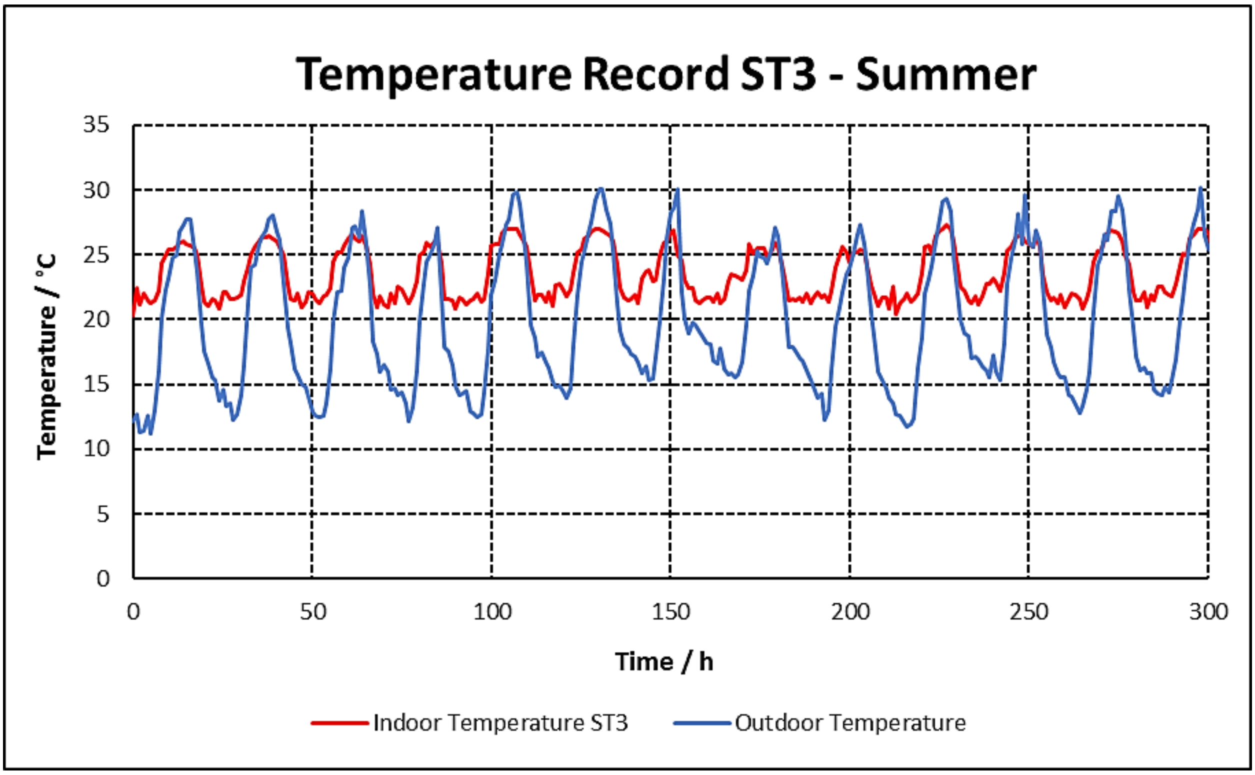


Fig. 70: Temperature record ST3 - Summer, Source: Own illustration

However, the climate control system has problems with very high temperatures in the summer. If the outdoor temperature rises, the indoor temperature also starts rising.

The temperature record for the poultry house ST4, which is illustrated in Fig. 71, was made at the same time as the record from ST3. The temperature regulation in the summer is much better in the henhouse ST4 compared to ST3. The reason for this very good result are the two cooling combs. This constant temperature helps the animals to feel comfortable in the henhouse. Furthermore, the great climate supports the egg laying performance and helps against diseases.

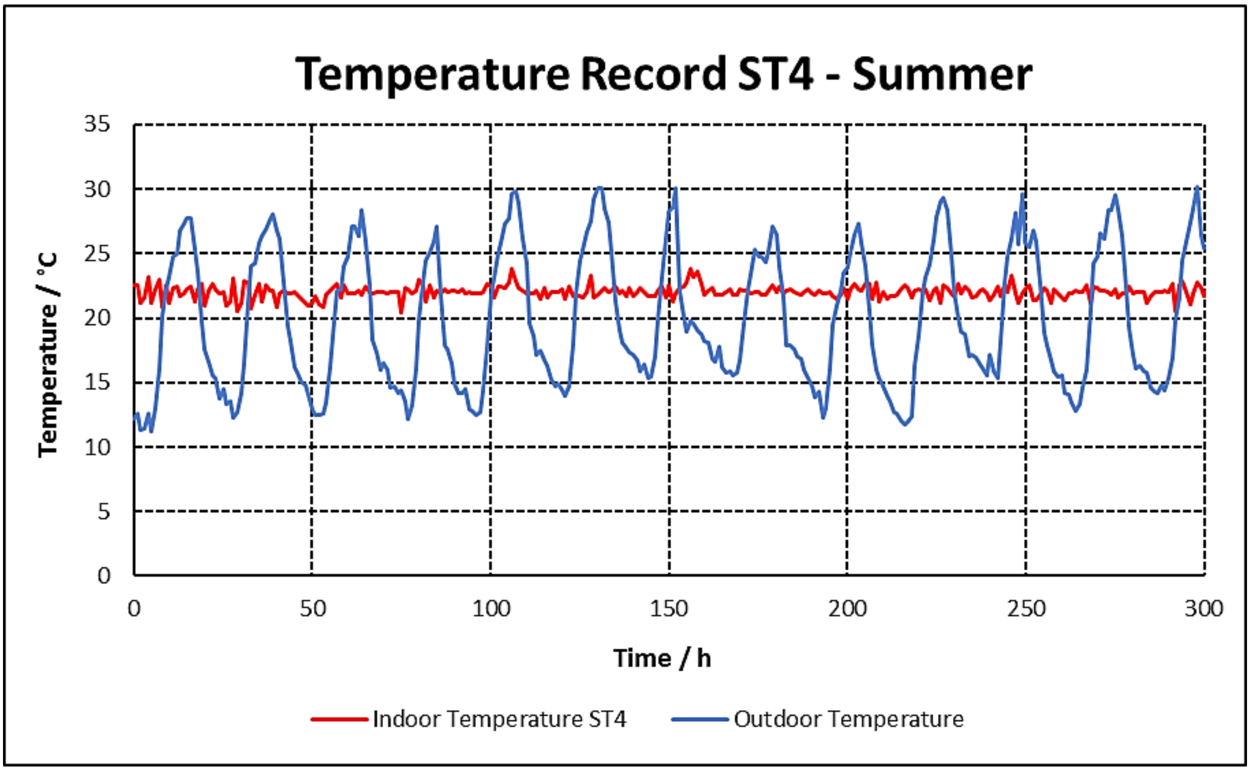


Fig. 71: Temperature record ST4 - Summer, Source: Own illustration

There were also temperature records made in the autumn to compare the two buildings by lower outdoor temperatures. The adjusted desired temperature for the next two diagrams is 22 °C. Fig. 72 shows a temperature record from ST3 which was made in autumn.

As can be seen, the climate control system for ST3 has problems with lower temperatures. In this record, there are three temperature drops where the indoor temperature is under 20 °C. Short temperature drops like these three are not very healthy for the animals, because this can have a negative effect on the laying performance.

However, in this record the outdoor temperature is over 0 °C which is not close to the lowest outdoor temperature in the winter in Austria. Therefore, very low outdoor temperatures can definitely have a negative effect on the animal's health and on the egg laying performance in ST3.

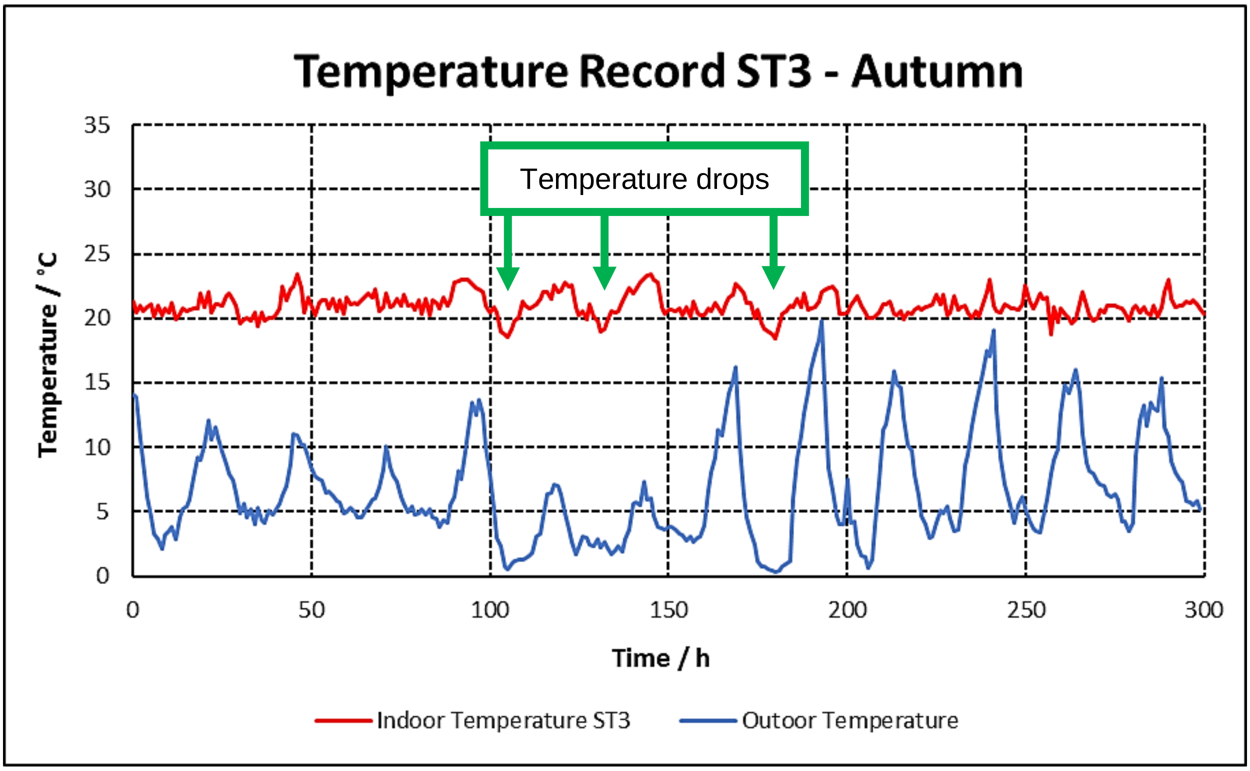


Fig. 72: Temperature record ST3 - Autumn, Source: Own illustration

Fig. 73. Illustrates the temperature record from the new henhouse ST4 in autumn. In the diagram, it can be seen that the indoor temperature is nearly constant, although the outdoor temperature has strong temperature drops. During this measurement record, the heat exchanger was working and prevented the indoor temperature drops. This diagram shows the excellent cooperation between all the electronic climate components.

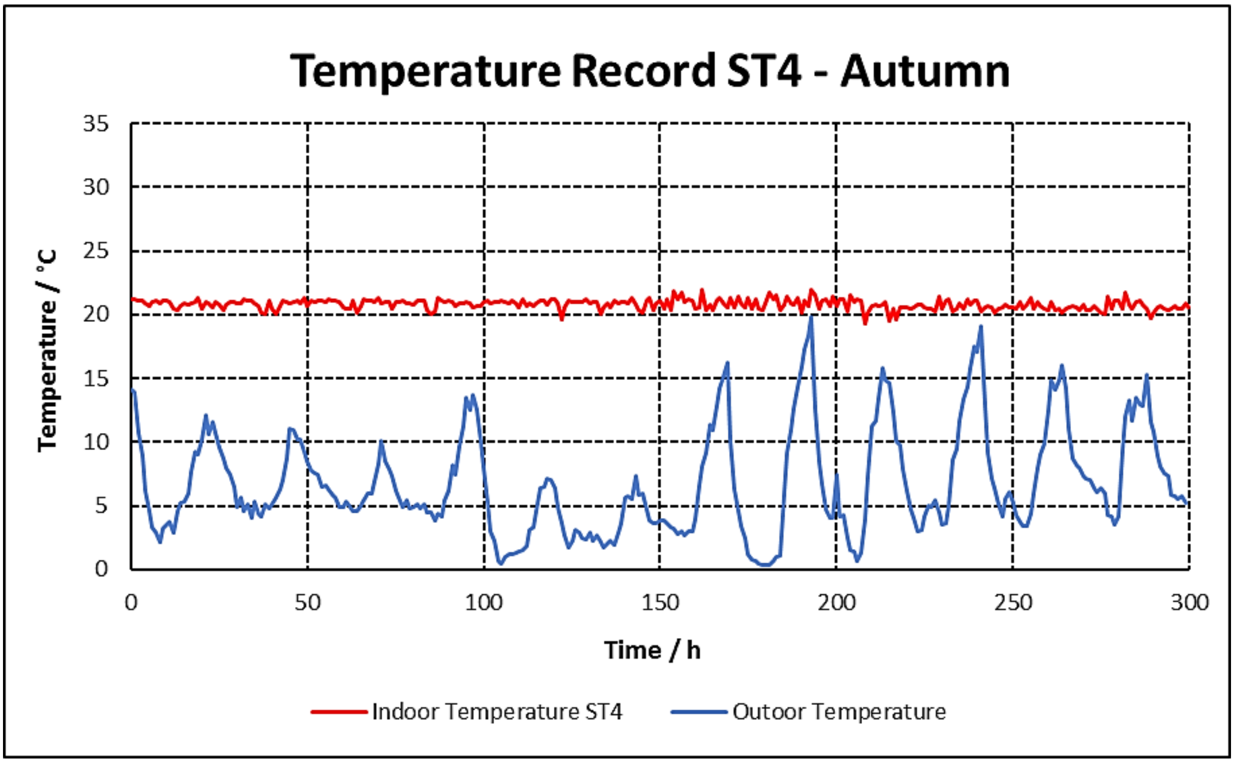


Fig. 73: Temperature record ST4 - Autumn, Source: Own illustration

The ideal relative humidity of the air in the broiler breeder building should be between 60 and 78 %. However, it is not very easy to control this value in the henhouse, because the relative humidity depends on a lot of environmental influences. Among other things the humidity in the building depends on the outside temperature and the outside humidity of the air, because the ventilators suck this air into the building. However, the relative humidity in the house is low when the outside temperature is low. If the relative humidity is very high, the litter on the floor can be wet. Furthermore, the indoor humidity can be influenced by the ventilation system. [68]

The humidity diagram, which is shown in Fig. 74, was recorded in autumn and represents the relative humidity from the henhouse ST3. As can be seen, the relative humidity varied between 55 and 77 %. This humidity level is not ideal, because the humidity sometimes gets lower than 60 %, but it is not critical. A ventilation system that is not well thought out can create these high fluctuations. It has to be mentioned, that the relative humidity in the summer is much higher, because the outdoor temperature is higher.

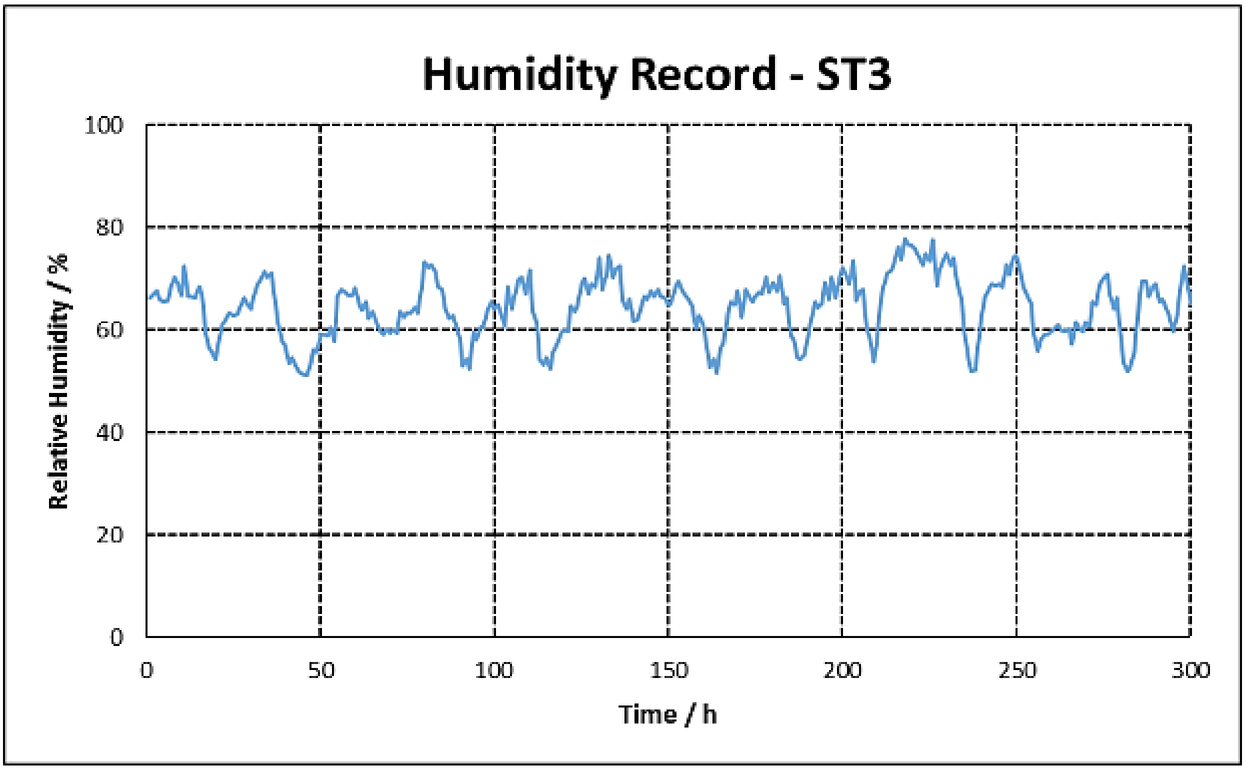


Fig. 74: Relative humidity – ST3, Source: Own illustration

[68] Cf. Leeson/Summer (2009), pp. 220-223.

The fluctuation of the relative humidity (Fig. 75) value from ST4 is not as high as in the henhouse ST3. A reason for the better regulation is the sophisticated climate control system of ST4. It is the combination of a lot of influences which generates a better relative humidity compared to ST3.

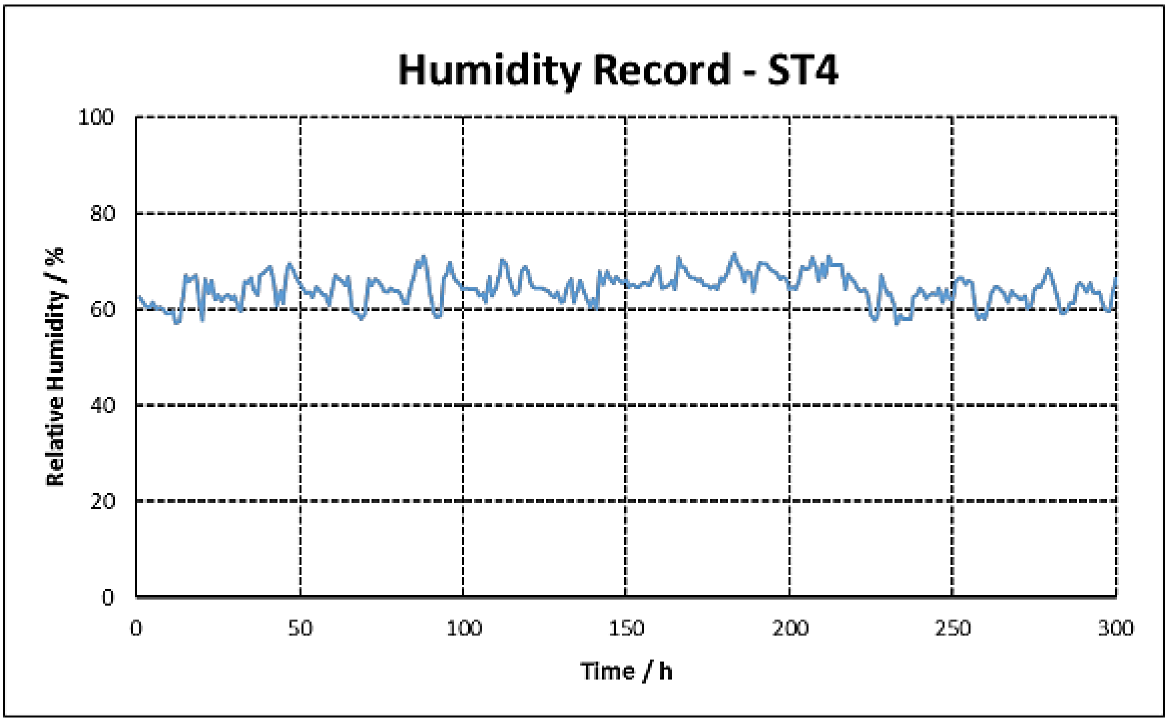


Fig. 75: Relative humidity - ST4, Source: Own illustration

However, there is one thing that can be done to create a better relative humidity situation in the winter. The problem in the winter time is the dry air that exists when the outdoor temperature very low is. A humidification system can be installed to rise the humidity level in the henhouse and to prevent the humidity level from getting too low.

6.4.2 Feeding system

The feeding system works very well in both henhouses, but the new feeding control system for ST4 has a few advantages. Especially the more sophisticated user interface makes it easier to change settings for the feeding supply. Furthermore, the operator has more setting options in the feeding control submenu compared to the feeding control system for ST3. Due to the versatile settings and management options, the operator can definitely create better and more constant feeding supply. Moreover, the new feeding concept with two fodder silos works very well and provides all animals with fodder at the selected time.

6.4.3 Egg collecting system

The safety function for the egg laying boxes, which prevents the chicken's injuries is very useful. There are two conveyor bands, which transport the eggs to the egg sorting room. Both of them can be accessed separately, which can be very useful. For instance, if there are maintenance works on one conveyor, it is possible that the second conveyor works and collects the eggs. Furthermore, the operator can set three running times for the egg conveyor band, which helps to spread the egg on the conveyor band. During the day, the conveyor band is started and runs only some seconds to change the position of the band. This process has the effect that eggs, which run from the egg box to the conveyor band, have more space on the band. With this method, the eggs are spread out more constantly on the egg band.

6.4.4 Water supply system

The water supply control system provides all the animals in the poultry house with fresh water. All magnet valves, which control the water pipes, work very well. The recorded water consumption is shown on the interface and the measured values are saved on the computer. Additionally, the safety feature checks every day if the drinking water consumption of the animals is sufficient. If there is something wrong, the operator is warned. Fig 76 illustrates the water consumption record of the henhouse ST4.

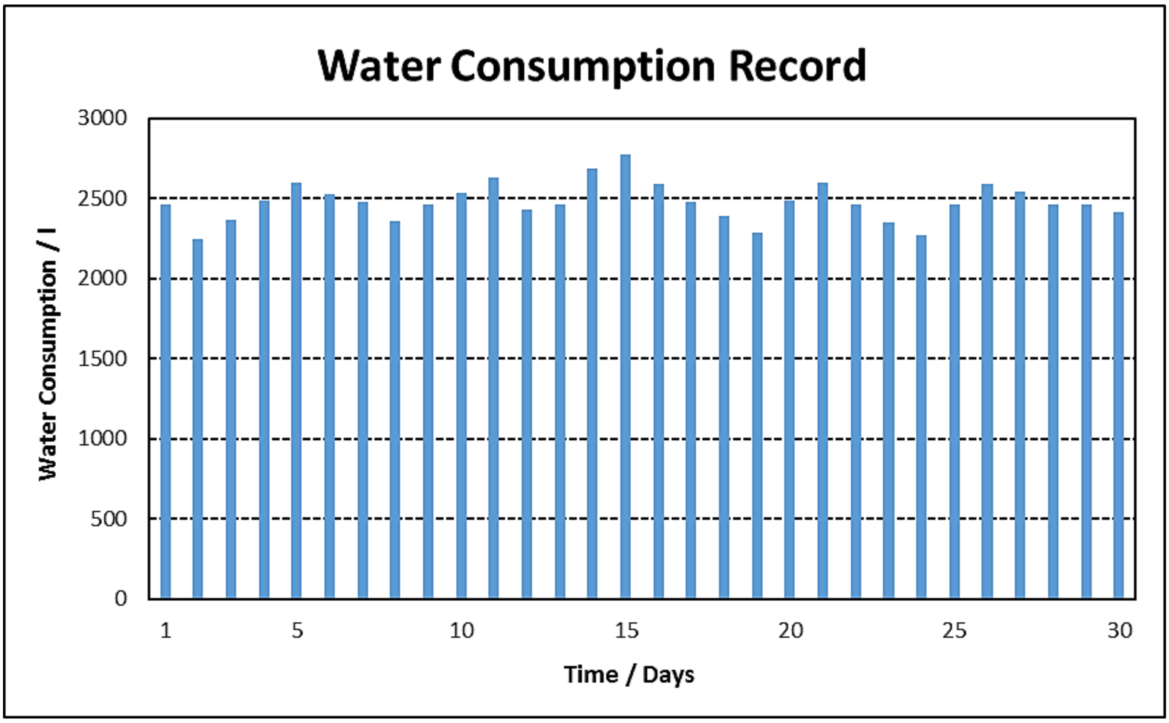


Fig. 76: Water consumption record, Source: Own illustration

6.4.5 Lighting system

The lighting recordings from light row 1 (Fig. 77) and light row 2 (Fig. 78) are different. Lighting line 2 is located near the egg laying boxes, because the lighting power level is lower compared to the lighting power level of light line 2. This has the effect that the chickens lay their eggs in the egg laying boxes. The user interface “Light control system” is clearly structured and the lighting control system works excellent. Furthermore, the slow switch-on and switch-off mode make the light changes more comfortable for the animals.

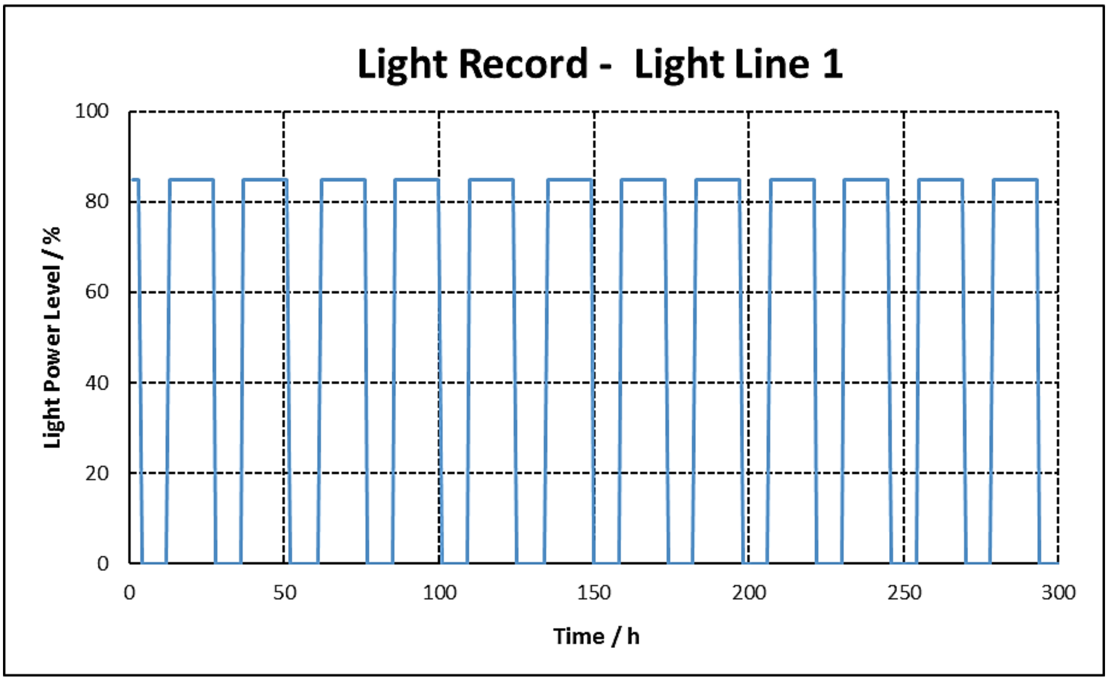


Fig. 77: Light record – light line 1, Source: Own illustration

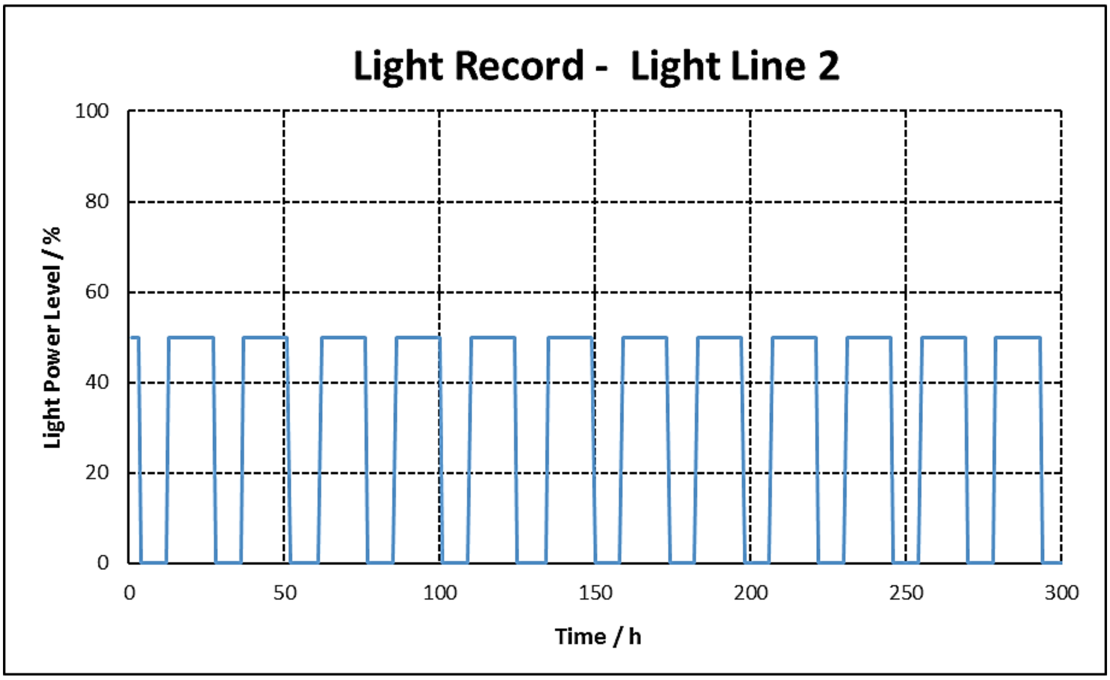


Fig. 78: Light record – light line 2, Source: Own illustration

7 CONCLUSION

7.1 Summary of the result

The concept of an automatized broiler breeder management building has been developed and implemented in the poultry house ST4. Furthermore, an economically priced and powerful industrial control processing unit has been implemented and is used to control the henhouse. The CPU can be programmed by a common software tool with a lot of comprehensive functions. This makes it simple and cheap to extend the control system for the henhouse at any time, if desired.

Moreover, a unique user interface has been developed to operate the broiler breeder management system. Since the owner and operator of the agricultural holding Taucher was involved in the designing process of the user interface at all times, the system fits his needs perfectly. A remote control function allows the user to operate the control system from far away via internet. Additionally, the new system is much cheaper than the old system, which is used in ST3. It is also cheaper than comparable control systems, offered by different companies. If there is a breakdown of current or a subsystem fails for whatever reason, the system offers a lot of safety features, such as automatic shutdown of subsystems and triggering of alarms. This makes it possible to support all the poultry animals for a few hours, which is absolutely crucial.

An extensive system test was carried out to check all the functions of the complete broiler breeder management system. Each sub control system has been tested separately and the most important measure quantities have been recorded. Judging from these recordings, it is possible to conclude that the new sophisticated climate control system for the henhouse ST4 is significantly better than the control system for ST3. It becomes apparent that the additional heat exchanger and the cooling combs have a positive effect on the climate in the henhouse and produce very good results. The heat exchanger makes it possible to generate a constant and very comfortable climate in the winter, when the outdoor temperatures are low. The cooling combs, on the other hand, support the henhouse with fresh, cool air in the summer, when the outdoor temperatures are very high. The cooperation of all these components produce outstanding climate results in the henhouse ST4. All the other sub control systems have some special features that the control system from the old henhouse ST3 does not have, which ensures that the performance and the safety of the whole system increases.

This developed control system has been running since the beginning of August 2016. Therefore, it is impossible to consider the egg laying performance of the chickens. Any system such as this needs a full year of testing to generate proper long term conclusions. All the chickens and roosters will be exchanged every year and after that it is possible to make a statement about their egg laying performance. However, it can be said that after four months of operating time, the chickens in ST4 lay more eggs than the chickens in ST3 over the same time period. All conclusions point to the fact that the egg laying performance will be considerably better with this new system. The new automatized broiler breeder management building will increase profits, productivity and overall animal welfare.

7.2 Outlook

The atomized broiler breeder management system works excellently, but there are a few functions that can be added in the future. In order to have a better control over the humidity in the building, a humidification system can be installed. Furthermore, a fully automated egg sorting robot can increase the productivity, as it would eliminate the need for a person to sort the eggs manually. Moreover, a better and especially more secure remote control system should be installed. However, the complete control system works perfectly and the customer, Mr. Taucher, is extremely satisfied with the result of this project.

Due to the fact that the new broiler breeder management system works very well, it will be used for another henhouse in the future. The agricultural holding Taucher is located in the district Hartberg in Styria and in this area, a lot of other chicken farms exist. In the last four months, several operators from chicken farms visited the farm Taucher to inspect the new control system and all of them were delighted. They were very impressed with the big and customized user interface, because most of them have a smaller and more complicated interface. They especially liked the variety of options and settings that this control system offers. Especially the well thought-out designed climate control system fascinated the other farmer experts. One of these enthusiastic farmers is expanding and building a bigger henhouse in the spring of 2017. This farmer has already committed to wanting to have the same control system as Mr. Taucher.

The next step is to start a company to sell this new control system to other farmers. The market for this product is very good in Austria, because there are a lot of chicken farmers in the countryside and a lot of them want to expand their agricultural holding and there is high demand for a simple, efficient and customized control system.

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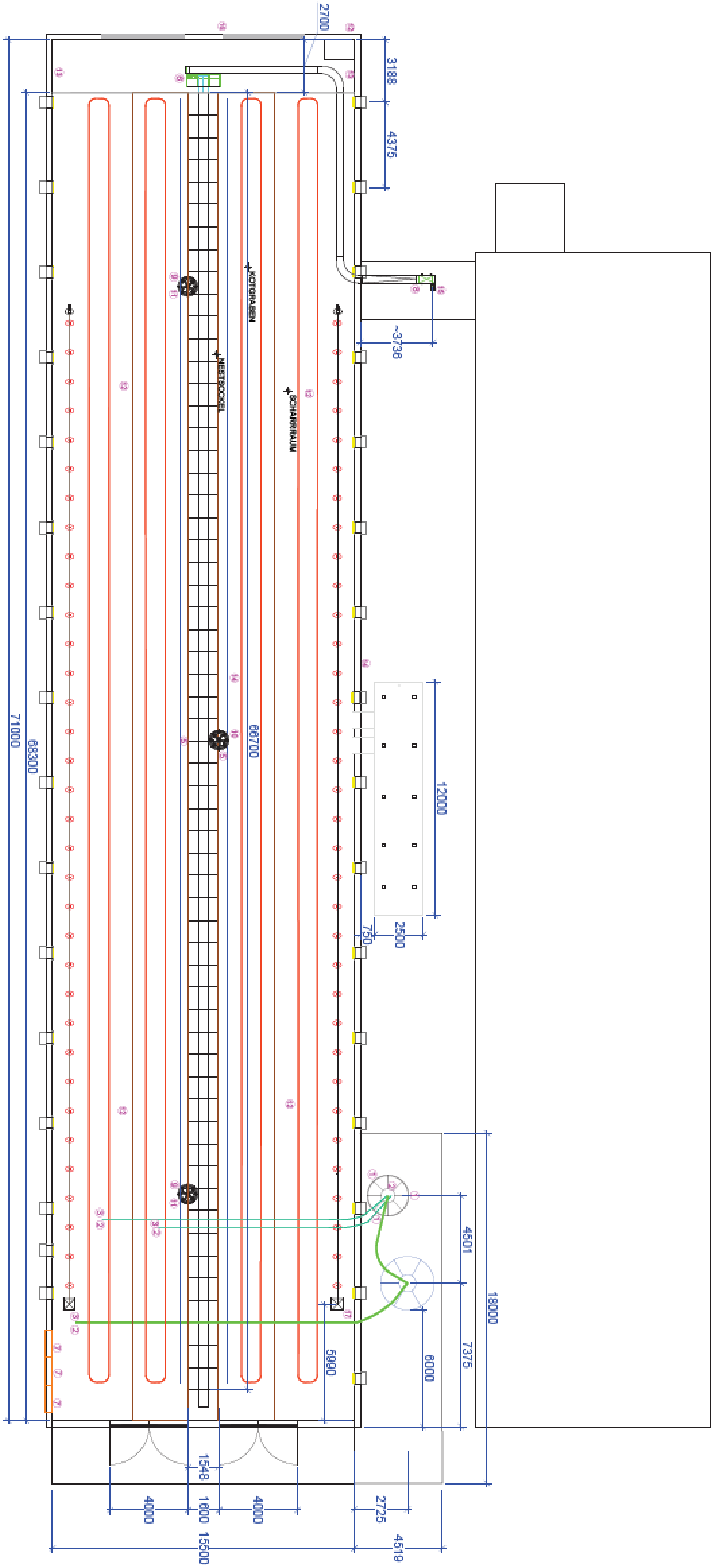
LIST OF FIGURES

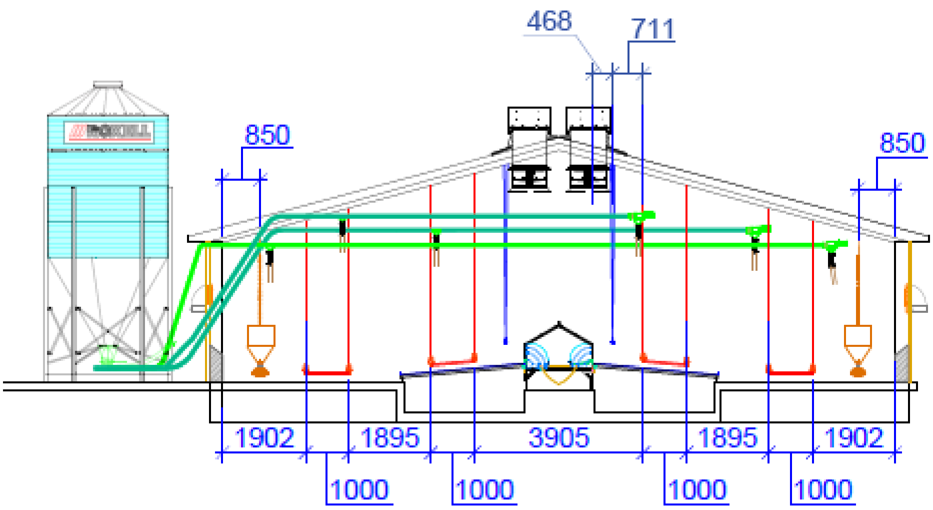
LIST OF ABBREVATIONS

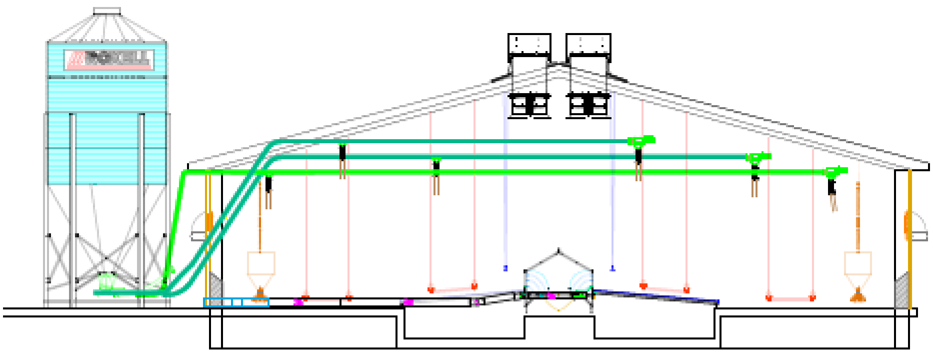
ST1	Stall 1 (henhouse 1)
ST2	Stall 2 (henhouse 2)
ST3	Stall 3 (henhouse 3)
ST4	Stall 4 (henhouse 4)
GSM	Global System for Mobile Communications
TIA	Totally Integrated Automation Portal
STL	Statement List
FBD	Function Block Diagram
LAD	Ladder Logic
GPRS	General Packet Radio Service
CPU	Central Processing Unit
LED	Light Emitting Diode
TIA	Totally Integrated Automation
UPS	Uninterruptible Power Supply

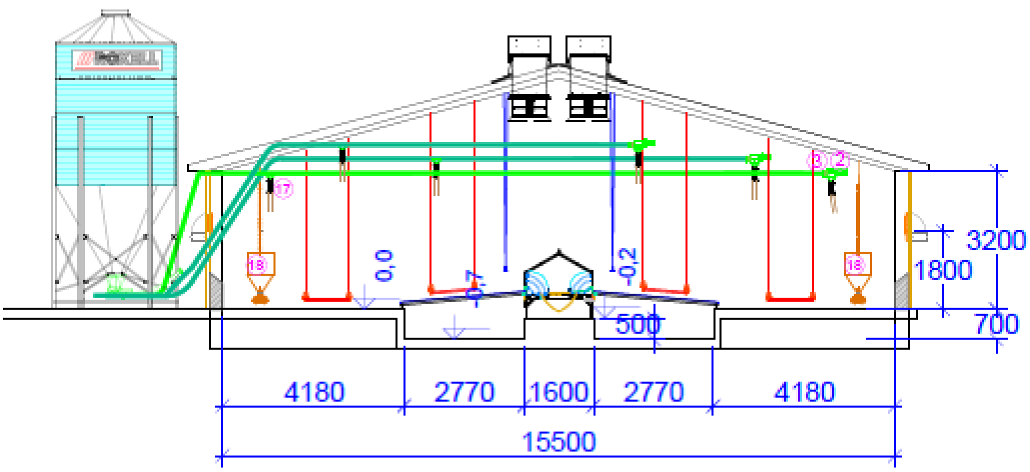
APPENDIX



71000
68300
66700
2700
3188
4375
~3736
12000
2500
750
4501
7375
18000
6000
5980
1548
4000
1600
4000
2725
15500
4519
KOTGRABEN
NESTSOCKEL
SCHARRRAUM


468
711
850
850
1902
1895
3905
1895
1902
1000
1000
1000
1000

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-0,7
-0,2
500
3200
1800
700
4180
2770
1600
2770
4180
15500

General specifications and features

Table 1 General

Technical data	CPU 1215C AC/DC/Relay	CPU 1215C DC/DC/Relay	CPU 1215C DC/DC/DC
Order number	6ES7 215-1BG31-0XB0	6ES7 215-1HG31-0XB0	6ES7 215-1AG31-0XB0
Dimensions W x H x D (mm)	130 x 100 x 75	130 x 100 x 75	130 x 100 x 75
Shipping weight	550 grams	585 grams	520 grams
Power dissipation	14 W	12 W	12 W
Current available (SM and CM bus)	1600 mA max. (5 VDC)	1600 mA max. (5 VDC)	1600 mA max. (5 VDC)
Current available (24 VDC)	400 mA max. (sensor power)	400 mA max. (sensor power)	400 mA max. (sensor power)
Digital input current consumption (24VDC)	4 mA/input used	4 mA/input used	4 mA/input used

Table 2 CPU features

Technical data		Description
User memory[1]	Work	100 Kbytes
	Load	4 Mbytes, internal, expandable up to SD card size
	Retentive	10 Kbytes
On-board digital I/O		14 inputs/10 outputs
On-board analog I/O		2 inputs/2 outputs
Process image size		1024 bytes of inputs (I)/1024 bytes of outputs (Q)
Bit memory (M)		8192 bytes
Temporary (local) memory		• 16 Kbytes for startup and program cycle (including associated FBs and FCs) • 4 Kbytes for standard interrupt events including FBs and FCs • 4 Kbytes for error interrupt events including FBs and FCs
Signal modules expansion		8 SMs max.
SB, CB, BB expansion		1 max.
Communication module expansion		3 CMs max.
High-speed counters		6 total, see table HSC input assignments for CPU 1215C • Single phase: 3 at 100 kHz and 3 at 30 kHz clock rate • Quadrature phase: 3 at 80 kHz and 3 at 20 kHz clock rate
Pulse outputs [2]		4
Pulse catch inputs		14