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Submitted (Author(s))	Ragnar Warnecke, Volker Müller, GKS	
Verified (WP-leader)	Robert van Kessel, TNO	2008-02-18
Approved (SP-leader)	Robert van Kessel, TNO	2008-02-18

Author(s)			
Name	Organisation	E-mail	Tel
Warnecke, Ragnar	GKS	ragnar.warnecke @gks-sw.de	+49(9721)6580-120
Müller, Volker	GKS	volker.mueller@gks-sw.de	+49(9721)6580-125

Abstract
<p>For a waste-to-energy plant the combustion control system (CC) is most important concerning the performance of the plant. Therefore the choice of the fitting system is extremely relevant for the plant efficiency.</p> <p>In general there are four different combustion control systems:</p> <ul style="list-style-type: none"> • Proportional-Integral-Differential (PID) • Fuzzy Control (FC) • Neuronal artificial networks (NN) • Model control (MC). <p>GKS has chosen a PID system with indirect coupling to the distributed control system (DCS) by decision matrixes as the most promising. The installed system delivers a very stable combustion situation. The comparison of the new operation data with the data before revamping, delivered an excellent improvement. The flexibility of the installed system offers a further improvement with a model based control subsystem.</p>

TABLE OF CONTENTS

	Page
1 INTRODUCTION	3
1.1 GKS Plant	3
1.2 Combustion Control – Motivation and Basics	7
2 KINDS OF COMBUSTION CONTROL SYSTEMS	11
2.1 Overview	11
2.2 Control systems	12
2.2.1 Proportional-Integral-Differential Control (PID)	13
2.2.2 Fuzzy Control (FC)	13
2.2.3 Neuronal Artificial Network (NN)	14
2.2.4 Model Control (MC)	14
2.3 Combination of Control Systems	14
2.4 Coupling of Control Systems in the District Control System	15
3 SELECTION OF AN ADVANCED COMBUSTION CONTROL SYSTEM	17
4 DESCRIPTION OF THE NEW ADVANCED COMBUSTION CONTROL SYSTEM	19
4.1 Detailed description	19
4.2 Main differences between old and new combustion controller	24
4.2.1 Air flow	24
4.2.2 Height of the fuel bed	25
4.2.3 Oxygen control	25
5 EVALUATION OF THE NEW ADVANCED COMBUSTION CONTROL SYSTEM	26
6 SUMMARY AND OUTLOOK	30

1 INTRODUCTION

Waste is produced by all of us. To avoid diseases, caused by biological reaction of waste and vermin, waste has to be handled responsible. The recovery of waste by converting it to energy is a most ecological and economical way. The combustion treats the waste without danger to health and is sustainable by avoiding other resources, e.g. fossil fuel.

1.1 GKS Plant

GKS was founded in 1987 to supply heat and power to local shareholders. In 1990 the plan for building a coal power plant providing environmentally friendly combined heat and power (CHP) for district heating was realized (Fig. 1.1).



Fig. 1.1: GKS plant

A thermal waste treatment plant was integrated into the CHP-plant since 1994. The residual waste of the Main-Rhön region is thermally recycled in these facilities and avoids the combustion of fossil coal by burning waste.

The waste-to-energy section of GKS consists of 3 lines in which about 180.000 t/a of waste are recovered by burning and converting into power and heat. A flow chart of the main plant is shown in Fig. 1.2.

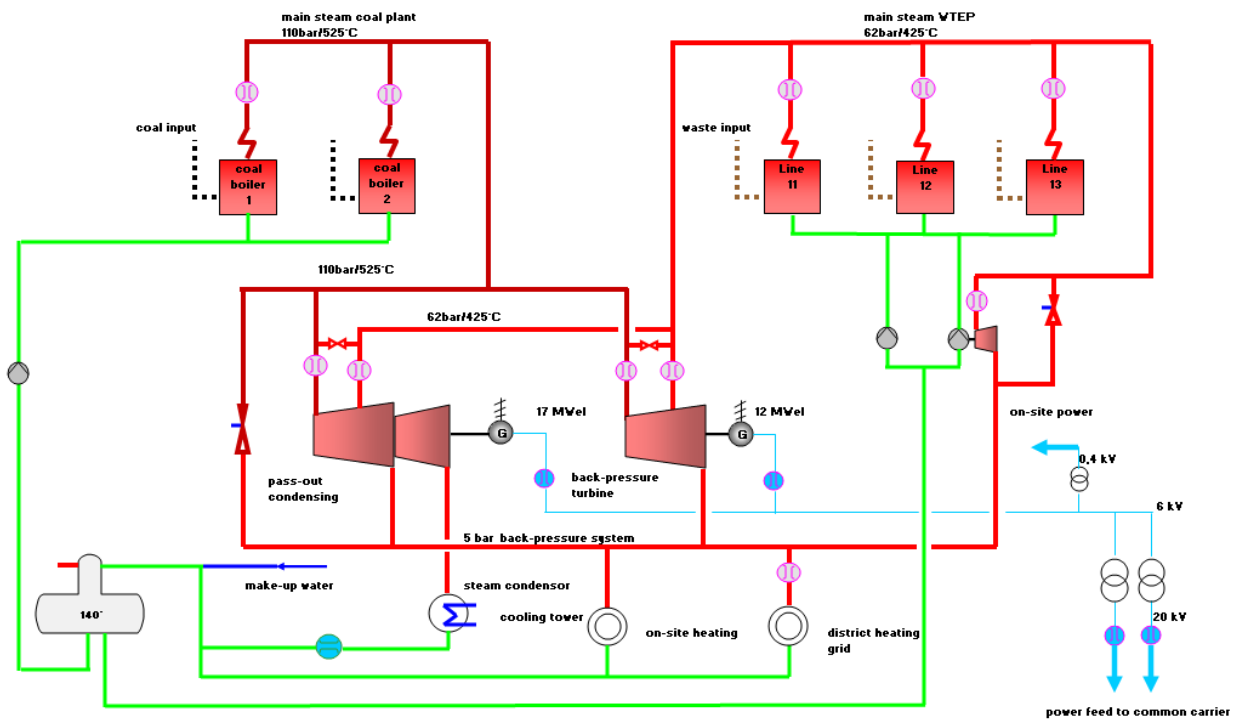


Fig. 1.2: Flow chart of GKS main plant

The waste from the bunker will be conveyed to the combustion chamber (see Fig. 1.3). The hot flue gases with a temperature of about 1.100 °C enter the 4-pass-boiler to transfer the heat to water and steam in the boiler tubes. The steam will achieve 435 °C at a pressure of 65 bars. The flue gas leaves the boiler at a temperature of 220 °C. In a multi-cyclone dust will be removed and in front of the following spray dryer additives for adsorption of heavy metals and dioxins are added. In the spray dryer the excess water from the scrubber has to be evaporated. The additives are captured in the following fabric filter. HCl and SO₂ are removed in the next unit that is a two-step scrubber. The scrubber is left by the clean flue gas at a temperature of 65 °C, is reheated to 105 °C and blown through the stack by a fan.

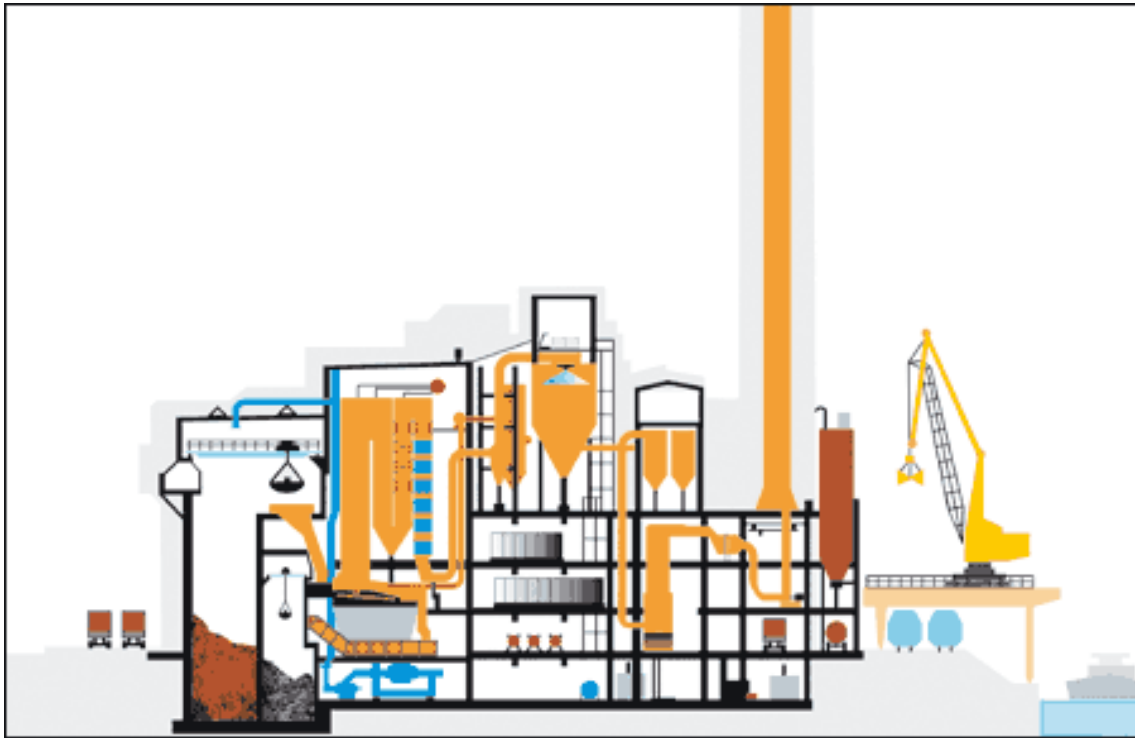


Fig. 1.3: Scheme of the waste-to-energy section of GKS

The steering of the plants power is mainly managed by the control of combustion chamber and boiler. A detailed plan can be seen in Fig. 1.4.



Fig. 1.4: Details of combustion chamber and boiler of the WtE-section of GKS

1.2 Combustion Control – Motivation and Basics

The combustion of a very heterogeneous material, as waste is, needs a complex control system if a stable combustion is aspired. A stable combustion is aspired to preserve the plant, to get a high efficiency and to avoid emissions. A controlled combustion allows to react to the most disturbances during operation and is able to run a plant in the optimal operation point. By an advanced combustion control system corrosion causing operation modes can be avoided and the efficiency can be increased by running the plant at the maximum load at any time.

To keep the combustion within an approved operation (that is normally defined in a combustion capacity diagram (Fig. 1.5)) measures have to be taken.



Firing Capacity Diagram

GKS Schweinfurt
Rev. 1

GKS-06-001-"2006"
25.07.2006

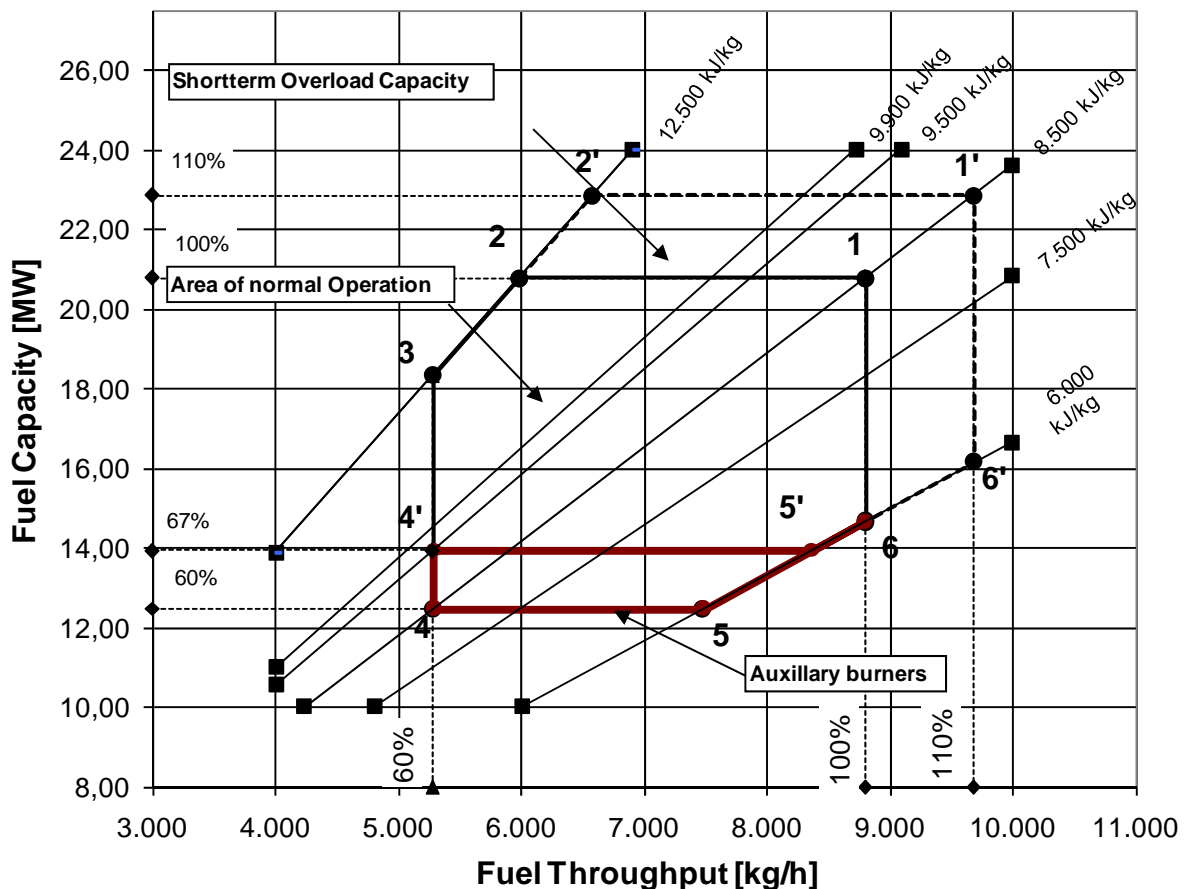


Fig. 1.5: Combustion Capacity Diagram for GKS

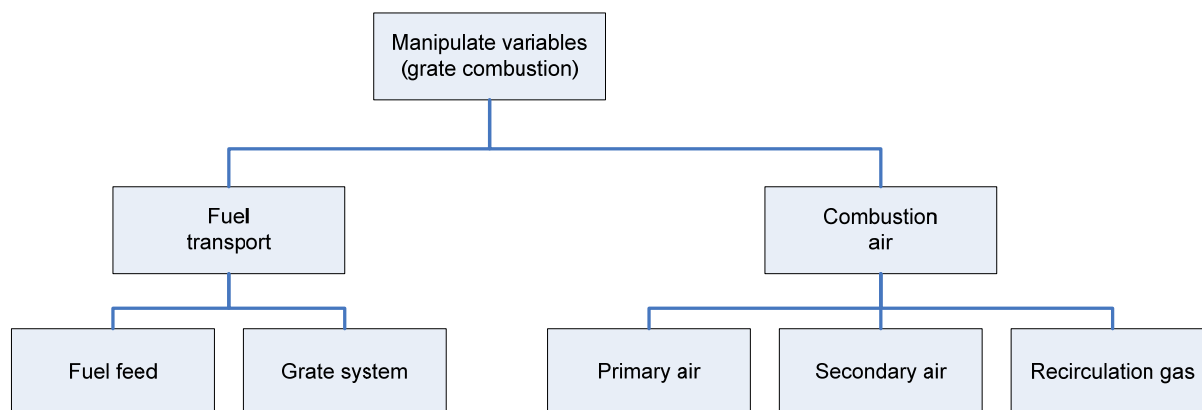


Fig. 1.6: Variables for a grate combustion which can be manipulated

Tab. 1-1: Explicit manipulate variables for the grate combustion at GKS (PA = primary air; SA = secondary air)

Combustion control			
	Primary manipulate variables		Secondary manip. variables
	Transport	Combustion Air	
Velocity fuel feed	PA zone 1	Total PA	
Velocity grate 1	PA zone 2		
Velocity grate 2	PA zone 3		
Velocity grate 3	PA zone 4		
	PA zone 5		
	PA temperature		
	Plate zone 1		
	Plate zone 2		
	Plate zone 3		
	Plate zone 4		
	SA	Switch of SA	
	Recirculation air		
Number of MV:	4	12	2

The number of measures to control the combustion is low. On the one hand side transport of the fuel (here: waste) can be steered and on the other side the air supply is a variable (see: Fig. 1.6).

The number of manipulate variables (MV) for GKS is **18** (Tab. 1-1). That means that 18 variables only can be taken to influence the process. Fig. 1.7 gives an overview over the manipulated variables in the process.

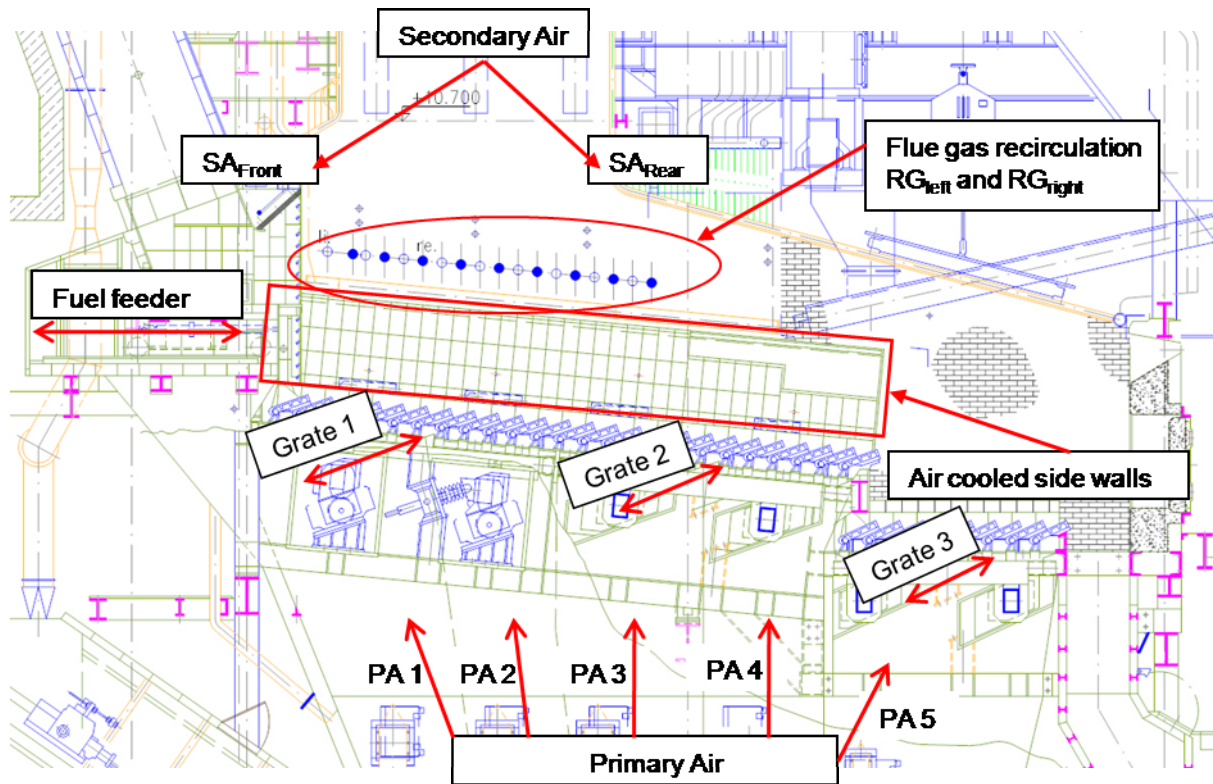


Fig. 1.7: Manipulated variables

To influence the process, the status of the process has to be known. Therefore numerous of parameters can be measured by sensors or calculated (Fig 1.8):

1. Manipulate variables MV (transport velocities; gas flows)
2. Control variables CV
 - a. Measured: concentration of species; gas temperatures
 - b. Calculated: heating value by energy balance etc.; height of the fuel bed
3. Disturbance variables DV (fuel mass flow; heating value etc.)

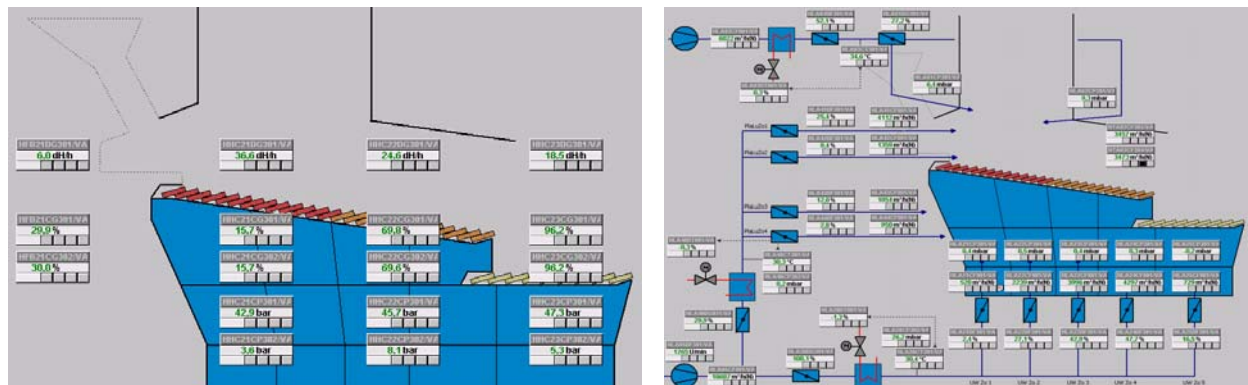


Fig. 1.8: Visualisation of variables at GKS

In the following there will be given an overview about:

1. different kinds of combustion control systems
2. selection of the combustion control system for GKS
3. description of the installed combustion control system
4. evaluation of the capability.

2 KINDS OF COMBUSTION CONTROL SYSTEMS

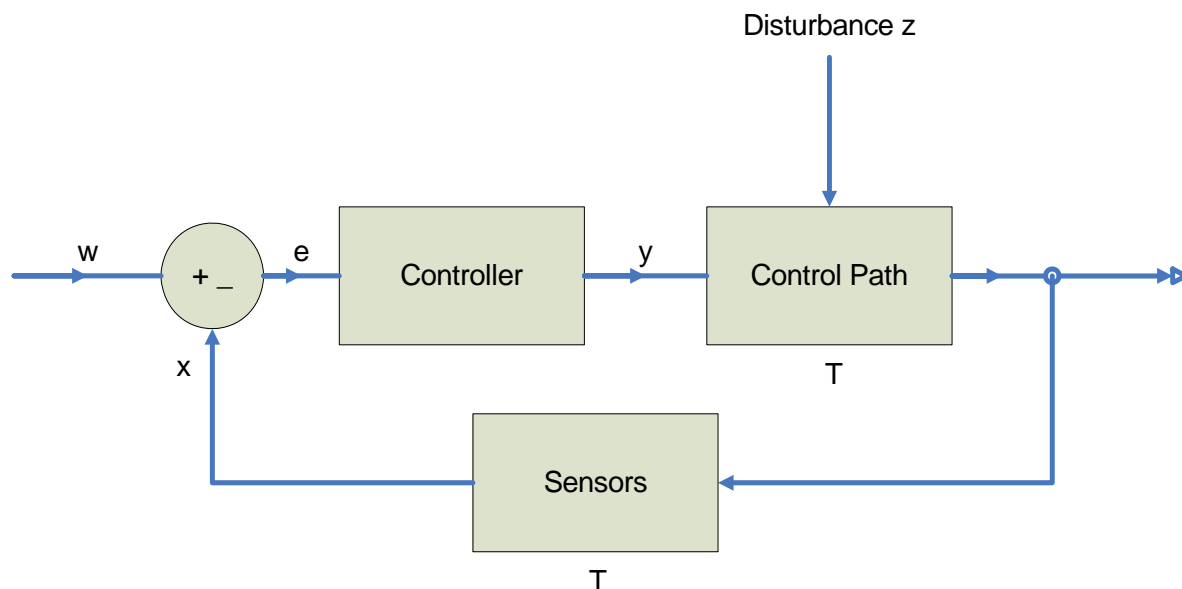
In general there are four kinds of combustion control systems:

- Proportional-Integral-Differential Control (PID) - conventional and advanced
- Fuzzy Control (FC)
- Neuronal Artificial Network (NN)
- Model Controlled (MC)

Each of these systems has its advantages and disadvantages.

2.1 Overview

For all control systems there is the same aim: To steer a process to a minimum offset between set-point and actual value (Fig. 2.1).



- w: Set-point value
- x: Actual value (feedback by sensors)
- e: Offset
- y: Manipulated variable
- z: Disturbance variable
- T: Reaction time in sensors and plant (control path)

Fig. 2.1: Control loop

The main value to be controlled in a boiler system is the **steam flow**. Beside that other variables can be controlled: temperature at the end of the grate (indicates the grade of combustion of the solid fuel); pressure over grate and fuel bed (can indicate local overload on the grate); temperature field over the fuel bed (indicates area of main combustion); oxygen content in the flue gas (indicates the grade of gas combustion) etc.

While integrating more than one control variable, the control system gets more and more complex (Fig. 2.2).

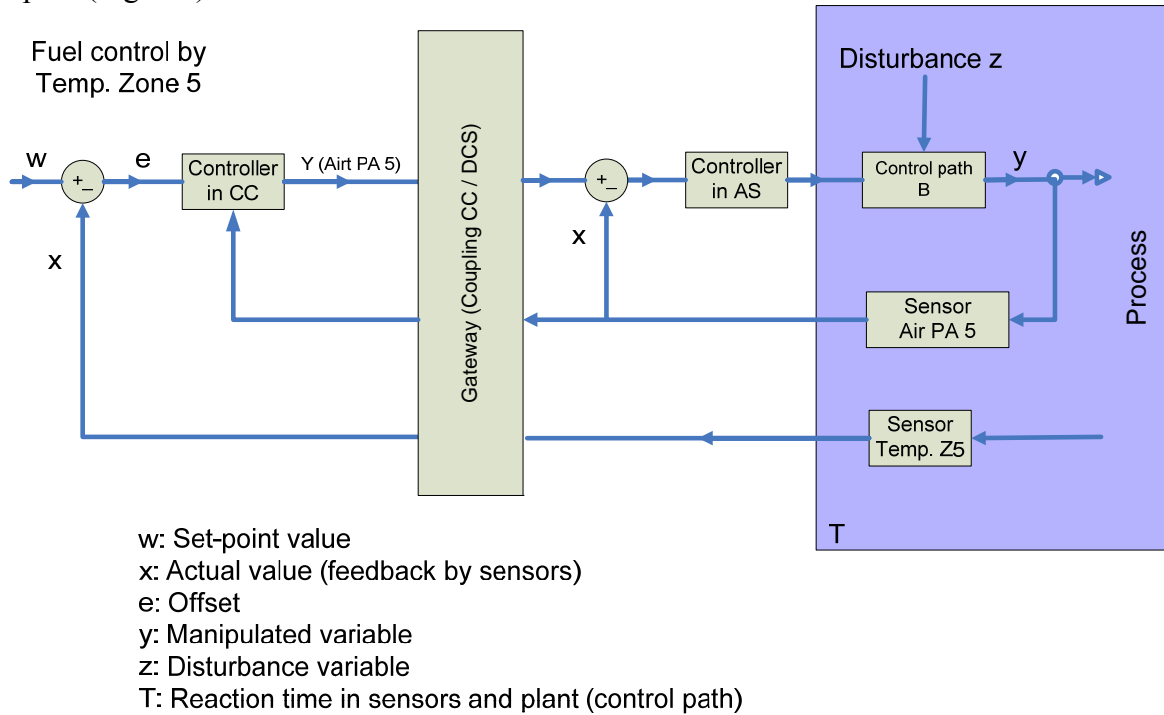


Fig. 2.2: Increasing of complexity of a control system with more controlled variables (CC = Combustion Control; DCS = Distributed Control System; AS = Automation System)

2.2 Control systems

The control systems, as mentioned above, can be use as single systems or can be combined (Fig. 2.3). The single systems are described below.

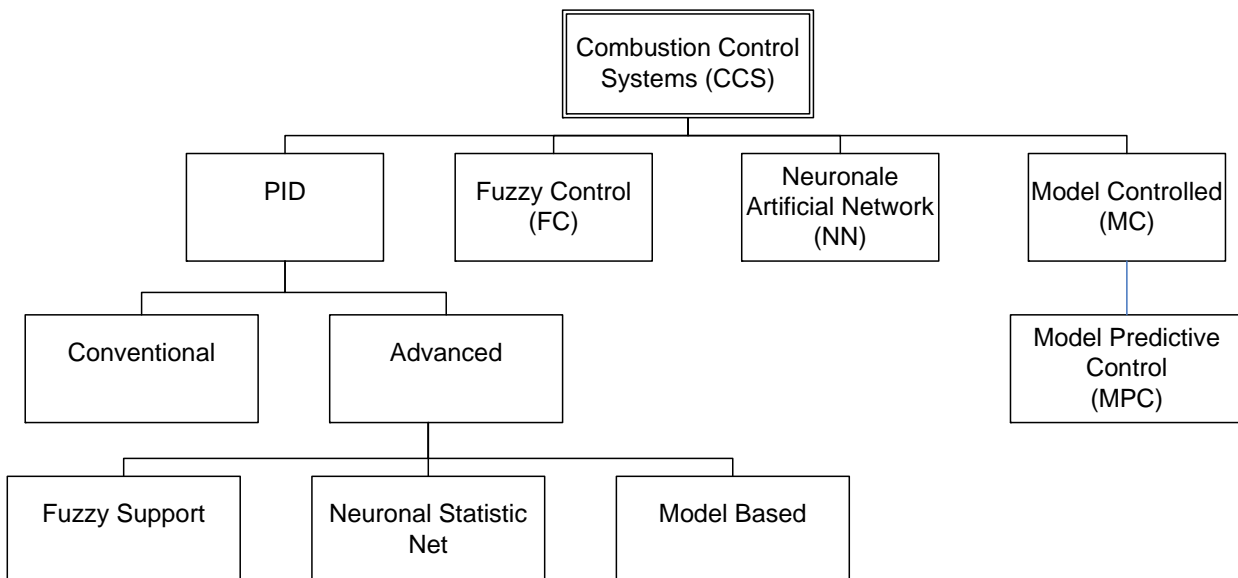


Fig. 2.3: Kinds of Combustion Control Systems

2.2.1 Proportional-Integral-Differential Control (PID)

The PID-controller consists of three components, which are added to one single manipulated value.

P-unit: The actual value behaves proportional to the offset. The proportional controller multiplies the offset with an amplification factor **K_p** and transfers the result directly. A P-controlled circuit is simple and can be characterised as medium fast. The disadvantage is a remaining offset.

I-unit: The integral acting controller sums up the offset over the time and multiplies the sum (i.e. the integral) with the factor **K_i**. The longer the offset is present, the more the manipulated variable of the I-unit will increase. The I-controlled circuit can be characterised as slow. The advantage is that the offset will be eliminated completely.

D-unit: The D-unit appraise the change of an offset (he differentiates) and calculates the velocity of change. This will be multiplied by the factor **K_d**. The D-unit is very fast but not able to work alone. It has to be combined with a P-unit and/or a PI-unit.

If the D-unit is added to the P-unit, the PD-controller reacts on the indication of a change. This leads to a kind of prediction within the control.

The combination of P- and I-unit to a PI-controller brings the advantages of a P-unit (fast reaction), with the advantage of the I-unit (precise compensation). The PI-controller is therefore precise and medium fast.

The PID-controller is the universal, classic controller. He units the good attributes of all controller components. The PID-controlled circuit is precise and very fast. The application of a PID-controller in WtE-plants is the “conventional” controller method. Within the use of these controllers there is a wide range of quality.

2.2.2 Fuzzy Control (FC)

The Fuzzy-controller is a non-linear characteristic field controller. For low-complex systems it supplies high transparency with good flexibility. The Fuzzy-controller is predestined to integrate knowledge of the operator into the controller on a linguistically base. Therefore the operator must not understand the controller and the user must not think about a complex model. Premise is that the necessary knowledge is available.

If the combustion control, as it is at GKS, is nearly to 100 % in automatic operation, the know-how of the local operator is not that distinctive. In general the FC is installed in some plants, where some experience had been made.

The Fuzzy-controller defines manipulated variable of the offset by three steps: fuzzyfying, fuzzy-Inference and de-fuzzyfying. The fuzzyfying delivers a linguistic variable for every actual variable with weighing the relation between “true” = 1 and “false” = 0. The fuzzy-inference is the formulation of Boole’ian-logical connectivity (similar as “if..., than ...”-relations). The de-fuzzyfying turns the linguistic description of the problem into a mathematical relation via weights of normally triangles or trapezes and their mathematical centre of gravity.

A further development of controller systems is the combination of fuzzy-controller and neuronal artificial networks.

2.2.3 Neuronal Artificial Network (NN)

The neuronal artificial network (NN) bases on the imitation of nature, that build networks of crosspoints (neurons) – e.g. in the brain. These neurons process single simple tasks. Connected together to a complex network they are able to solve complex control tasks.

The NN must learn the process and plant behaviour in a teaching phase before the operation at the plant (e.g. in a similar plant). The learned control situations can be extended during to operation time at the plant. If the computer performance is good enough, a probable prediction of the plant behaviour in the near future can be realised. Neuronal artificial networks are, in a way, statistical systems which are able to solve stochastic problems. A disadvantage of NN is that not learned situations can not be solved and the plant can, in the worst case, run in damage. This could happen when the plant runs into a situation in which the NN has no information from the past. In other words NN models cannot be used for extrapolation.

2.2.4 Model Control (MC)

Basis of this type of controller are physical and chemical models which describe the process. There are two different model control systems: model predictive control (MPC) and model based control (MBC).

Model based control (MBC) systems are normally not able to steer a process by themselves. They need another controller to complete the control circuit. There are no model based controllers known for WtE-plants as the new system of GKS which is coupled with a PID system. So the model based control system is presented in Fig. 2.3 as a part of the PID-controller.

The model predictive controller (MPC) is able to steer the whole process independent of other controllers. In general there is a problem with the excellence of the model in relation to the real plant. The MPC is also able to predict a short time of operation and therefore can react anticipatory. The anticipation is right, if the model is good enough, what is difficult for complex processes with hardly predictive disturbance variables.

2.3 Combination of Control Systems

The optimisation of complex processes with important disturbance variables will lead to some combinations of controller systems. It is realised a FC/NN-combination, while the results are not convincing. The problem of these combined control systems is on the other hand the price and the complexity of the system.

2.4 Coupling of Control Systems in the District Control System

For the integration of the control system there are two ways:

- Direct integration
- Indirect coupling.

The direct integration into the DCS means the integration of the program within the software of the CS. The advantage is that there is one programming language and system for CS and DCS. The main disadvantage is that the complexity of the combustion controller has to be reduced to the options of the DCS if necessary.

The indirect coupling into the CS is realised by an electronic connection of the DCS to a separate computer station. The connection is implemented normally by a universal transfer protocol (e.g. OPC). The disadvantage is that there is a “black” (the system, especially the software, inside the computer is not known) or “white” (the operator knows the inside of the system and can influence the software) box with an independent hard- and software in it. The advantage is that there are more opportunities for the controller.

The combustion controller in GKS has an indirect coupling to the central control system coupled via Gateway (Fig. 2.4).

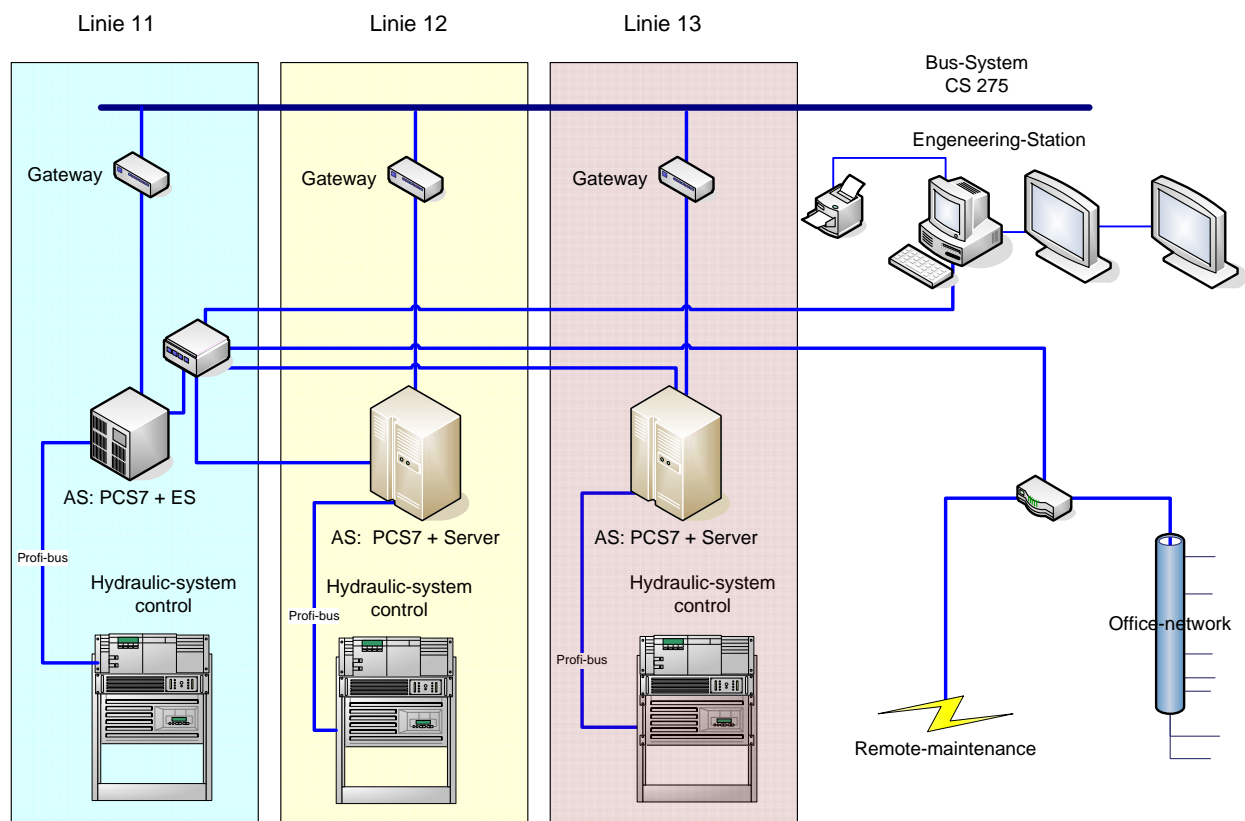


Fig. 2.4: Coupling of CC into DCS

The connection from the CC has to be realised by a gateway to the Siemens DCS via a bus system. A partially visualisation of manipulated and control variables must be managed in the DCS because of the operation of the plant is managed from this system. Some relevant screen shots are shown below (Fig. 2.5).

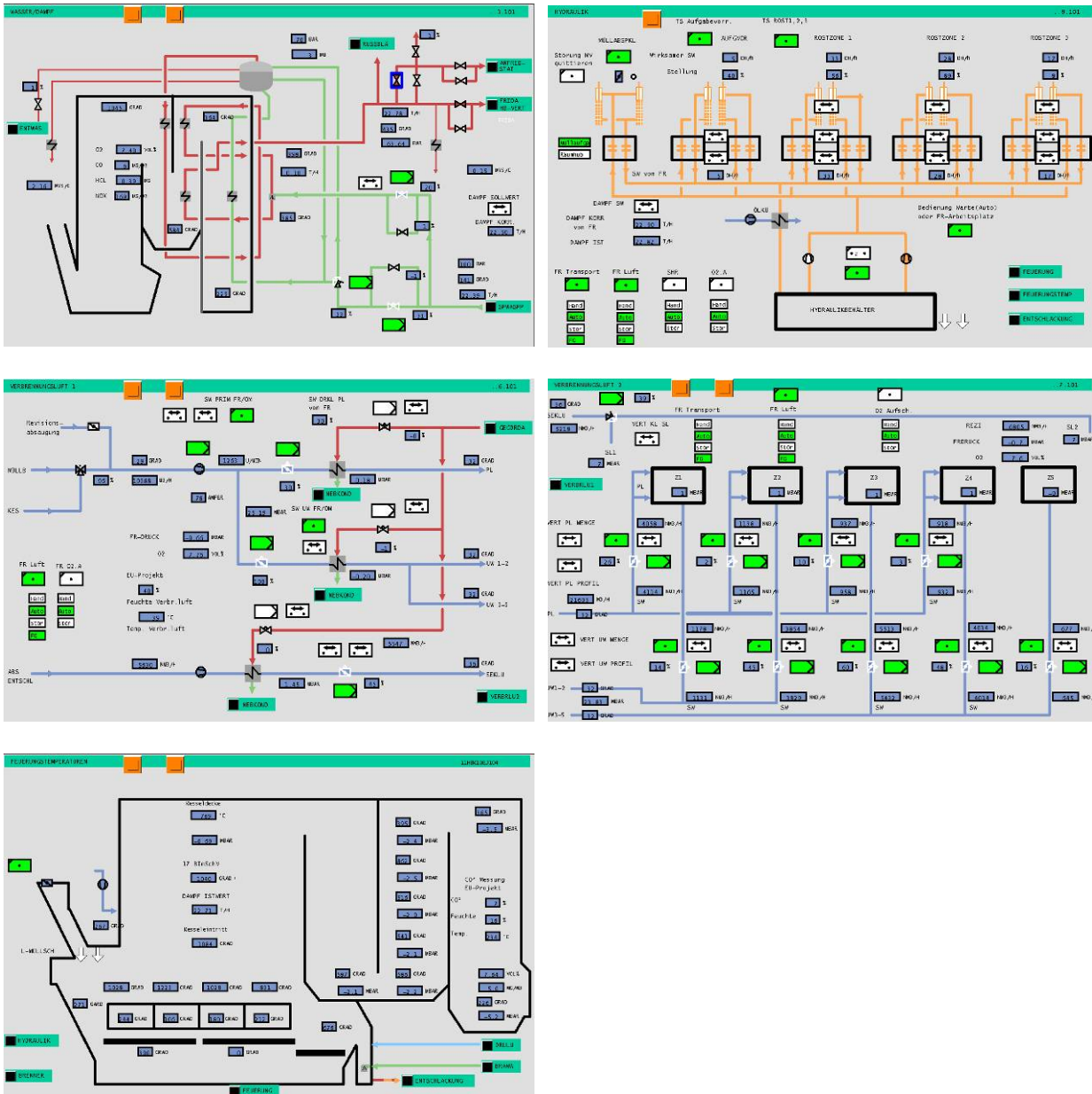


Fig. 2.5: Screen shots of the CS

3 SELECTION OF AN ADVANCED COMBUSTION CONTROL SYSTEM

The decision between the four control systems is difficult and in a way it is a question of the company’s philosophy. GKS developed the following decision matrix (Tab. 3-1).

Tab. 3-1: Decision matrix for combustion control system (++ = very good ... -- = very bad)

Control systems:→ Arguments:↓	PID	FC	NN	MPC
Experience of GKS control engineer	++	0	--	--
Acceptance of GKS operators	++	+	0	0
Physical/chemical/technical understanding by GKS staff	++	+	0	+
Reference situation of the suppliers in WtE-plants	++	+	-	-
Changes by GKS possible (without others)	++	--	--	--
Perspective in the future	++	0	+	++

Based on this matrix GKS decided for a PID-controller. Main aims were the reference situation and to get a system that is accepted and developable at GKS.

For choosing the supplier of an advanced PID system a new matrix was designed (Tab 3-2). (Examples for suppliers for the other systems are:

- FC: Gierend
- NN: Powitec
- MPC: TNO)

Tab. 3-2: Decision matrix for PID suppliers (last 4)

Companies:→ Arguments:↓	SAR, Dingolfing	Babcock-Noell, Würzburg	Thyssen-Krupp, Duisburg	KH-Automation, Fuldabrück
References in WtE-plants	++	++	0	-
Competence in discussion (controller/process engineering)	++	++	+	--
Flexibility for integration of MBC	++	+	-	-
Detail solutions	++	++	+	+
Price	++	++	0	0

Beside the control system itself the additional equipment for detecting the control variables is as important and the integration of these data into the control philosophy. Here is a potential to increase the system price very much. For example the NN-system was only offered with an infra-red camera which doubles the price of the system. On the other hand it has to be considered that the gained information of a detailed localised temperature profile over the width

of the grate can not be used because the primary air can not be varied over the width. Five infra-red temperature detectors (which cost about 10 % of an infrared camera) deliver the same useful information (combustion temperature over the length of the grate, which can be used to control the distribution of the primary air). The equipment for the main measurable control variables:

- Temperature
- Pressure
- Volume flow
- Concentration (e.g. O₂)

should be selected with respect to the control options.

4 DESCRIPTION OF THE NEW ADVANCED COMBUSTION CONTROL SYSTEM

One of the premises of the installed combustion control system (CC) was to have a comprehensible structure. Together with GKS the supplier SAR developed an overview of the controller structure (Fig. 4.1). It can be seen, that there are two branches of each of the both groups of manipulated variables:

- Transport
- Combustion air.

Each branch contains a base tablet, a trimming tablet, a section for the weighing of the different variables and delivers at the end the set-values. Additionally a number of charts and data tables can be chosen.

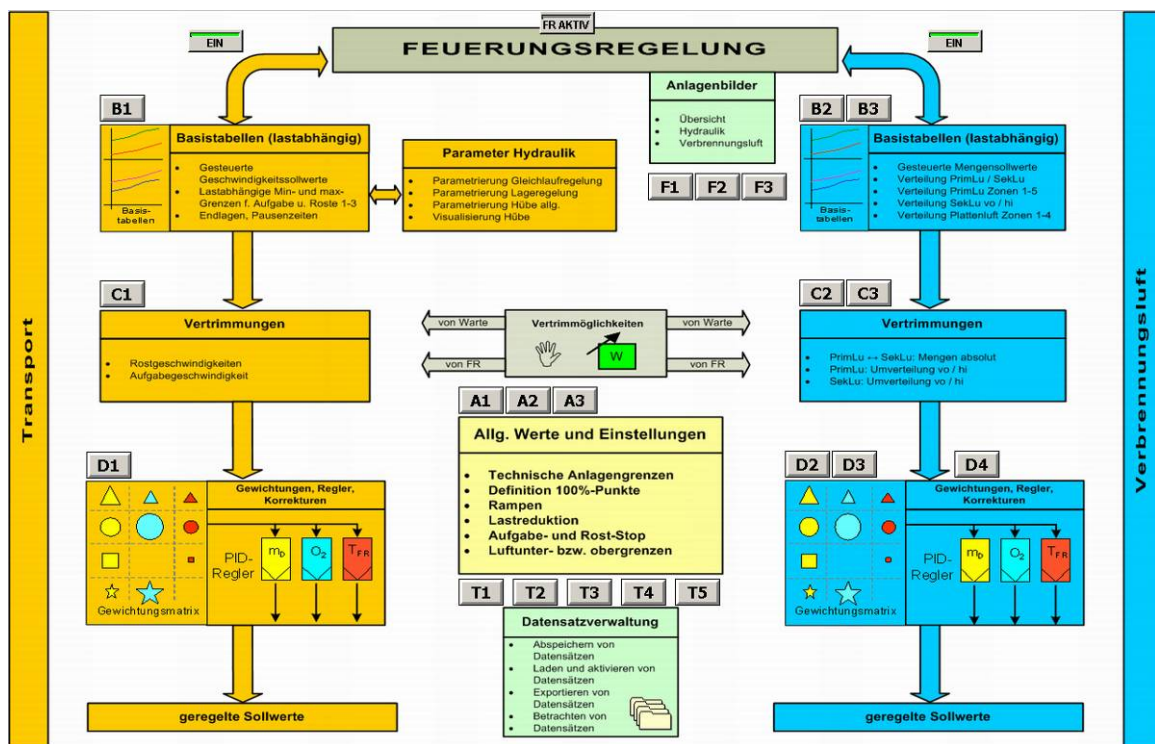


Fig. 4.1: Overview over the controller structure

4.1 Detailed description

At first in the base tablets the maximum and minimum performance of the plant has to be noted for the transportation and air supply (example for transportation: Fig. 4.2). It can be seen, that the maximum speed of the grate is defined as the maximum number of grate strokes per hour (dH/h). The maximum length of one stroke is 370 mm for the grate and 1,050 mm for the feeder.

The so called “base tables” (Fig. 4.3) give the relation between the plant load and the demand of fuel transport parameters respective of air flow variables. The data between the minimum load, here 60 %, and the maximum approved load of 110 % are given by theoretical calculations and

practical tests. In the table there can be seen the values of the 60 % load case at the left and the maximum load of 110 % at the right. In between there are the other load points in steps of 10 %. The actual value for example the air supply is calculated in the last row. The different flows are added reasonably at the right side of the table.

Technische Anlagengrenzen			
Aufgabe Hübe	100% =	16,4	dH/h
Rost 1 Hübe	100% =	300,0	dH/h
Rost 2 Hübe	100% =	300,0	dH/h
Rost 3 Hübe	100% =	180,0	dH/h
Aufgabe Hublänge	100% =	1150,0	mm
Rost 1 Hublänge	100% =	370,0	mm
Rost 2 Hublänge	100% =	370,0	mm
Rost 3 Hublänge	100% =	370,0	mm

Fig. 4.2: Maximum values for the transportation units

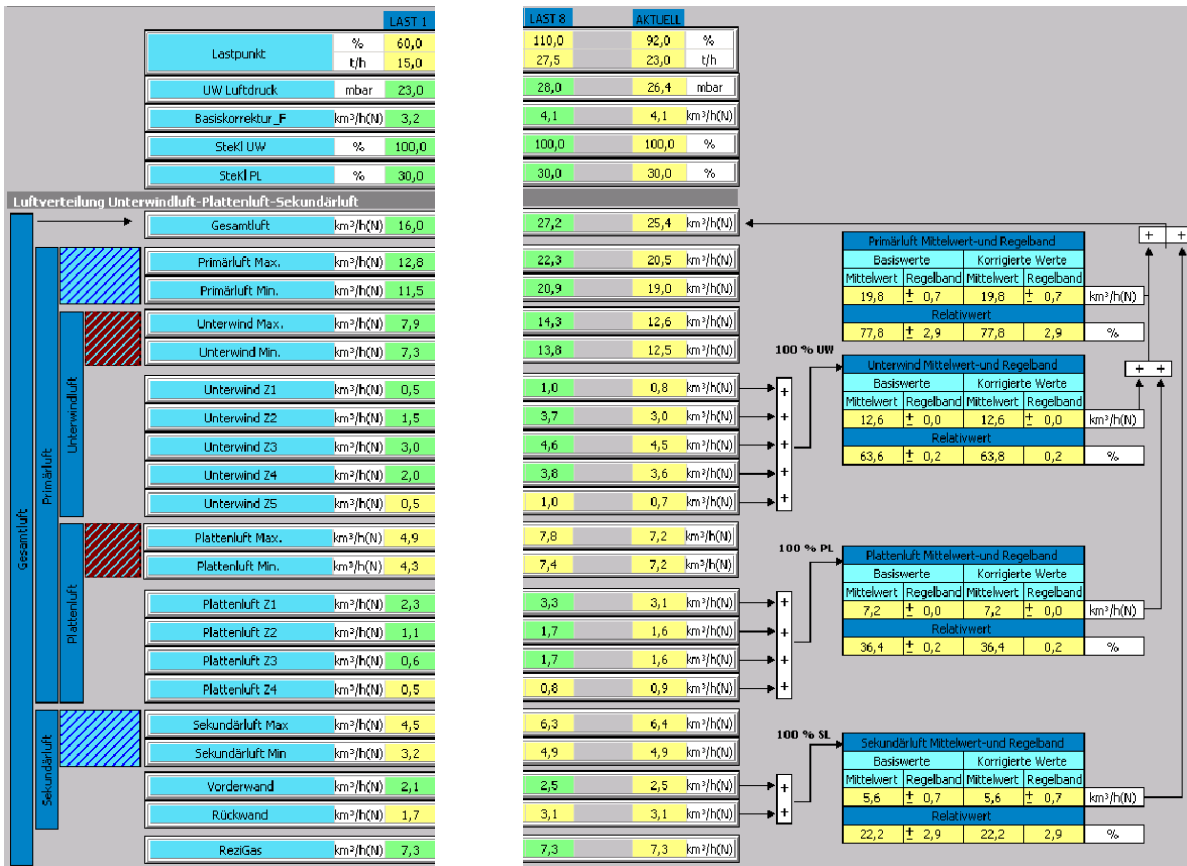


Fig. 4.3: “Base table” for air variables

A load change or a set-point variation shall not be too fast for the more or less low velocity of the overall system as the grate combustion is. Therefore ramp functions are integrated in the program and can be parameterised (Fig. 4.4).

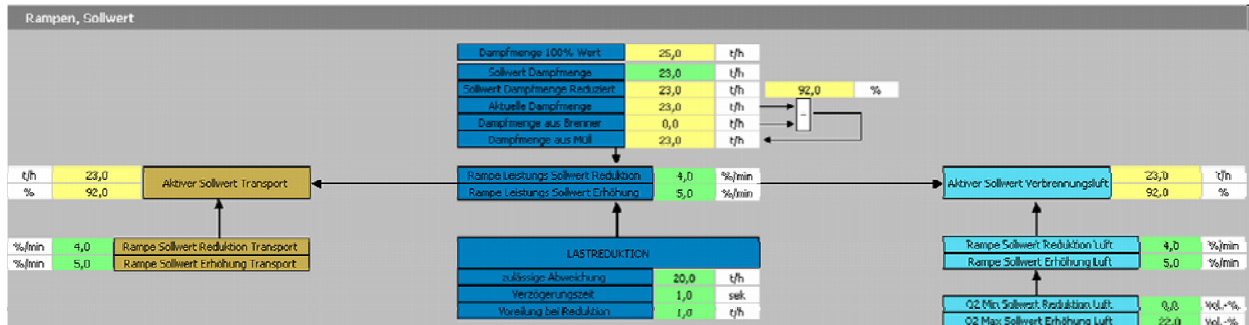


Fig. 4.4: Ramp function parameterisation

The calculated data from the base table can be trimmed by the operator to react on special situations on the grate (normally caused by the disturbance variable “waste”). The strength of the trimming can be defined in the combustion control program (Fig. 4.5).

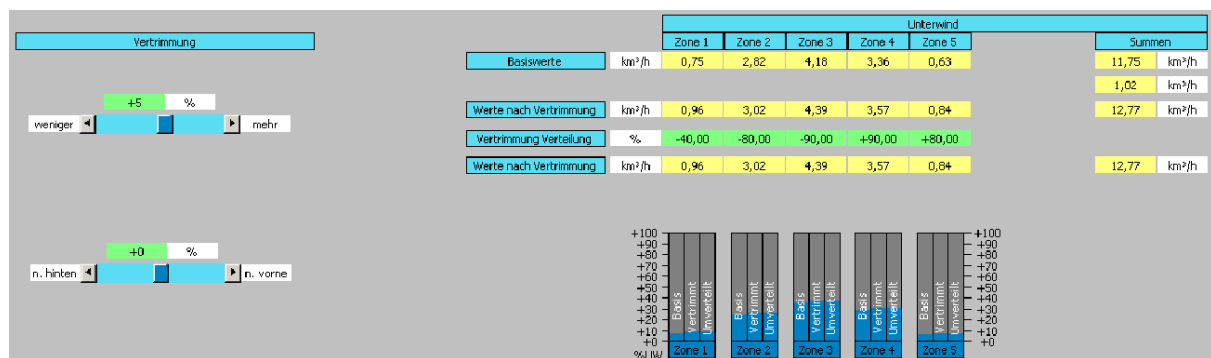


Fig. 4.5: Trimming of transport and air flow parameter (here primary air)

The data from the base table will be corrected by the trimming and deliver a new output value.

All the gained control and manipulable values have to be put into a relation to each other. Reason for that is that the tendency of one variable can for example have another direction as from another variable. Therefore a weighting is necessary. This weighting is done in a weighting table (Fig. 4.6).

The weighting table is one of the central units in the advanced combustion control system. It offers the possibility to weight the control variables in their influence on the manipulable variables. Within the advanced combustion control system the programming is that flexible, that it offers to add other control variables directly. In the future it will be very easy to integrate new control variables without changing the complete program (see EXT 1 to 6). Some of the external variables will be data taken out of the combustion model.

The weighted data are mathematically connected and the calculation (Fig. 4.7) delivers the values for the PID-controller (Fig. 4.8). The advanced PID-controller calculates the direct manipulated variable. In difference to normal PID-controllers several correction terms can be added.

	ZONE 1		ZONE 2	
	Gewichtung / Korrekturfakt.		Gewichtung / Korrekturfakt.	
Dampfmenge	+15,0	-0,01	+45,0	-0,03
O2-Luft	+0,0	+0,00	+15,0	-0,02
FT-Luft	+0,0	+0,00	+5,0	-0,03
Feuerraumtemp. Z1	+5,0	+0,05	+0,0	+0,00
Feuerraumtemp. Z2	+0,0	+0,00	+0,0	+0,00
Feuerraumtemp. Z3	-5,0	-0,03	-10,0	-0,05
EXT1	+0,0	+0,00	+0,0	+0,00
EXT2	+0,0	+0,00	+0,0	+0,00
EXT3	+0,0	+0,00	+0,0	+0,00
EXT4	+0,0	+0,00	+0,0	+0,00
EXT5	+0,0	+0,00	+0,0	+0,00
EXT6	+0,0	+0,00	+0,0	+0,00
Summe	+0,01		-0,13	
Basiswert	1,0 km ³ /h		3,0 km ³ /h	
Basiskor.	4,1 km ³ /h		4,1 km ³ /h	
Korrekturwert	0,1 km ³ /h		-0,5 km ³ /h	
Sollwert	1,0 km ³ /h		2,5 km ³ /h	

...

Fig. 4.6: Weighting of the control variables onto the manipulable variables in the “weighting table”

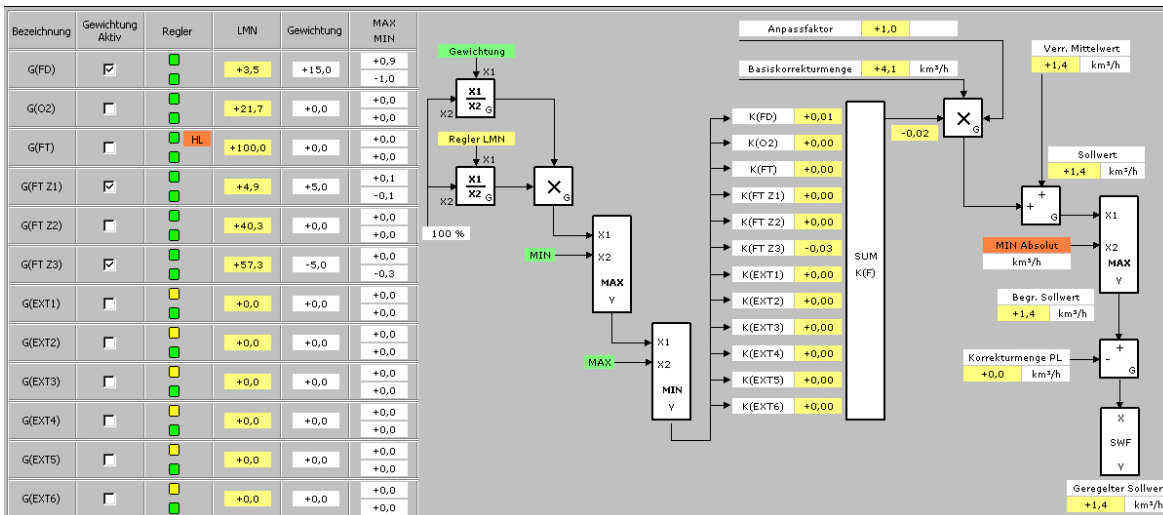


Fig. 4.7: Calculation of the “corrected” manipulated values

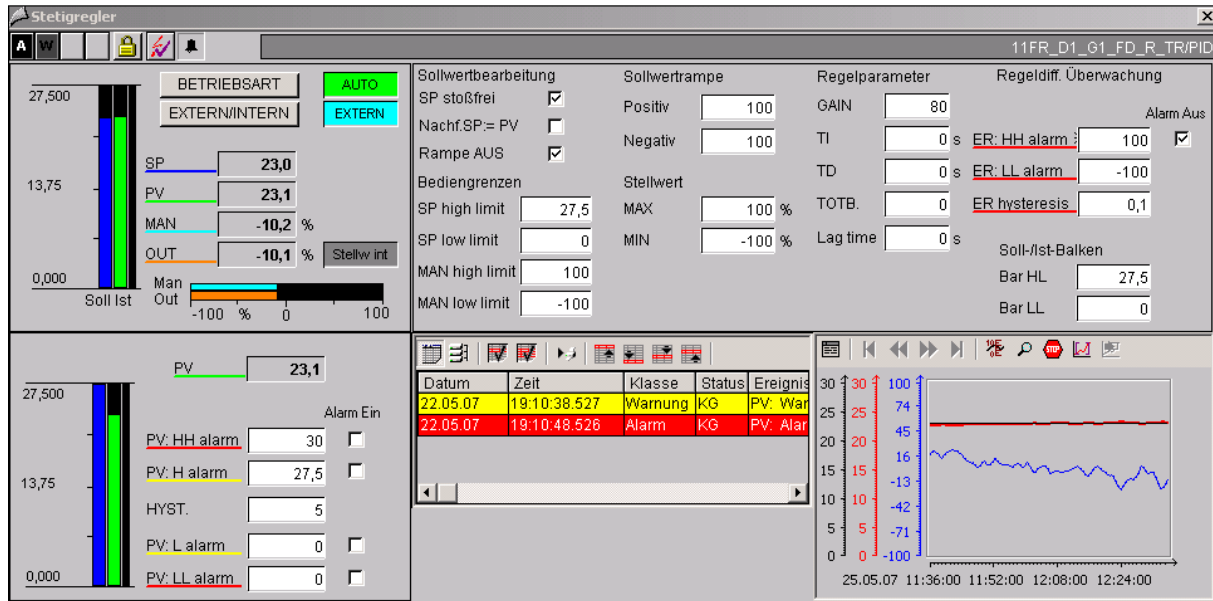


Fig. 4.8: Advanced PID-controller

All the data for the manipulated variables are visualised in one screen (Fig. 4.9). Here the base value, trimmed value, corrected value, set-point value and actual value for transportation and air supply are listed in a column diagram. By this tool the effects of all the control measures can be overviewed.

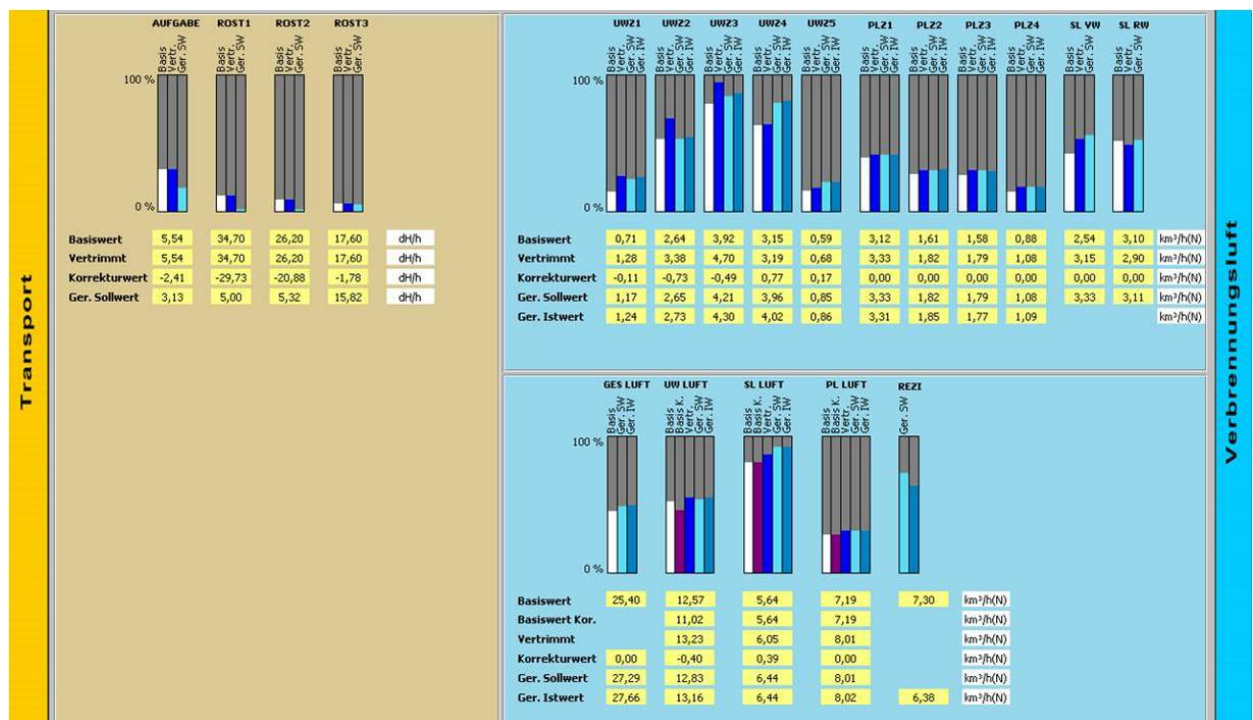


Fig. 4.9: Summed up overview for the manipulated variables as base value, trimmed value, corrected value, set-point value and actual value

To get an idea in which load the plant (respective the line) is running, a firing capacity diagram (FCD) visualises the situation. The position of the cross in Fig. 4.10 gives a fast view of the mechanical throughput (fuel in tonnes per hour), the firing capacity (in MW) and the lower heating value (in kJ/kg).

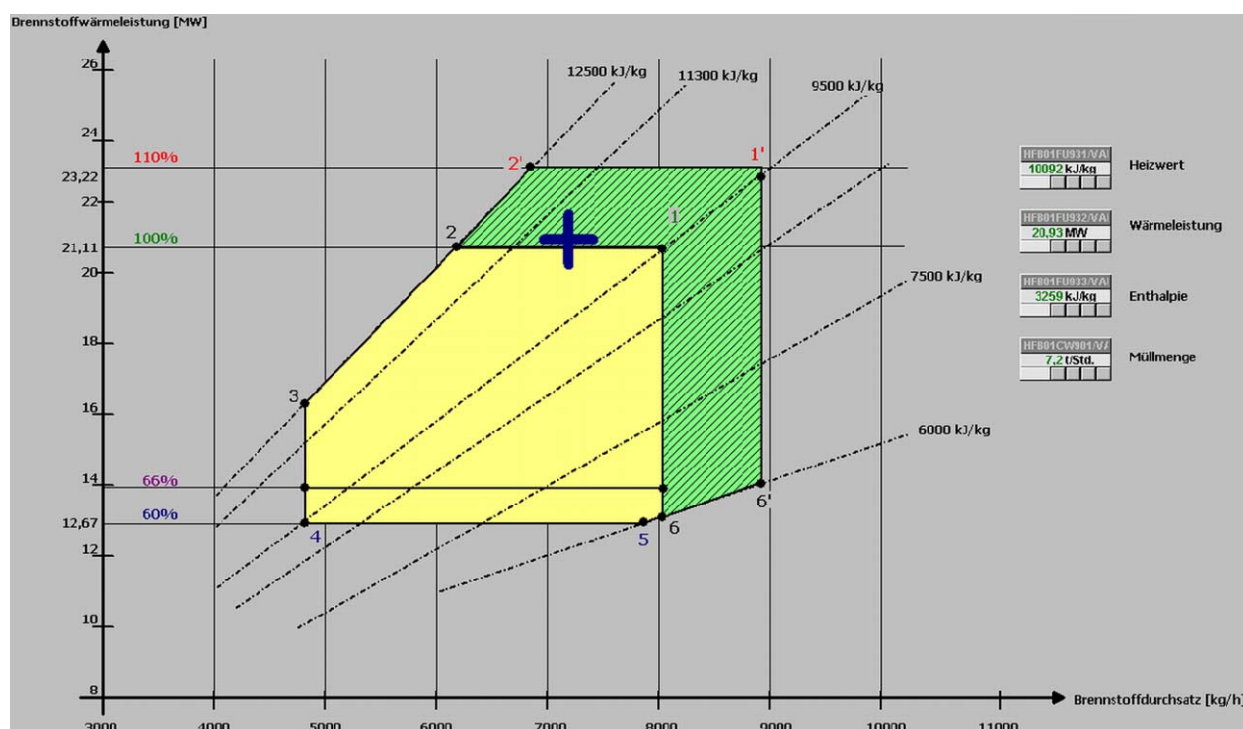


Fig. 4.10: Visualisation of the plant load within a firing capacity diagram (FCD)

4.2 Main differences between old and new combustion controller

Although the former combustion controller (CC) had been a PID-controller as well, the new advanced controller has some better and new features.

4.2.1 Air flow

In the old CC a change in the combustion situation was followed by a change of air flow between primary air (PA) and the air cooled side walls. This transfer is not given any more. Instead of this the PA is switched between the 5 zones (Fig. 4.11). A more direct effect on the combustion is induced and a better, independent control of the side wall temperature is possible.

A temperature influenced distribution over the five PA-zones is integrated. Therefore the temperatures in the combustion chamber are measured by infra-red detectors (zone 1 – 3) and thermocouple (zone 4 – 5).

Gewichtungen Regelung Unterwind										
	ZONE 1		ZONE 2		ZONE 3		ZONE 4		ZONE 5	
	Gewichtung / Korrekturfakt.		Gewichtung / Korrekturfakt.		Gewichtung / Korrekturfakt.		Gewichtung / Korrekturfakt.		Gewichtung / Korrekturfakt.	
Dampfmenge	+15,0	-0,01	+45,0	-0,03	+30,0	-0,02	-40,0	+0,03	-15,0	+0,01
O2-Luft	+0,0	+0,00	+15,0	-0,02	+20,0	-0,03	-25,0	+0,04	+0,0	+0,00
FT-Luft	+0,0	+0,00	+5,0	-0,03	+0,0	+0,00	-7,0	+0,04	+0,0	+0,00
Feuerraumtemp. Z1	+5,0	+0,05	+0,0	+0,00	-3,0	+0,00	-2,0	+0,00	+0,0	+0,00
Feuerraumtemp. Z2	+0,0	+0,00	+0,0	+0,00	+0,0	+0,00	+0,0	+0,00	+0,0	+0,00
Feuerraumtemp. Z3	-5,0	-0,03	-10,0	-0,05	-4,0	-0,02	+10,0	+0,05	+0,0	+0,00
EXT1	+0,0	+0,00	+0,0	+0,00	+0,0	+0,00	+0,0	+0,00	+0,0	+0,00

Fig. 4.11: Weighting of primary air

4.2.2 Height of the fuel bed

The height of the fuel bed is important because it can be, especially at the end of the grate, a synonym for complete or incomplete combustion. If for example a huge bulk of waste is not yet incinerated and lays on the grate in primary air zone 4 or 5, it can be assumed, that the remaining slag in the deslagger, when this fuel enters the deslagger, will not undercut the limit value of 3 % total carbon. Different methods to measure the bed height had been tested:

- Hydraulic pressure of the grate transport,
- Pressure drop of primary air through the grate bars and the fuel bed.

Unfortunately none of the both methods deliver reproducible results. The measurements were stopped and a calculation of the bulk on the grate out of the combustion model will be taken into consideration.

4.2.3 Oxygen control

The oxygen content in the boiler is in a strong relation to temperatures and to the volume flow of flue gas. The higher the oxygen content in the flue gas, the larger the volume flow. The flue gas fan has maximum capacity as a function of volume flow and pressure drop. Over the operation time, with increasing pressure drop, the capacity of the flue gas fan can be the bottle neck of the plant capacity. Therefore a reduction of the oxygen content can increase the capacity of the plant over the full operation time. That is the reason to include the optimisation of the oxygen content stronger into the new advanced combustion control system.

5 EVALUATION OF THE NEW ADVANCED COMBUSTION CONTROL SYSTEM

Normally for the comparison of two conditions of a plant line-diagrams over the linear time are taken. As can be seen in Fig. 5.1 the comparison is difficult and imprecise and can lead to incorrect conclusions.

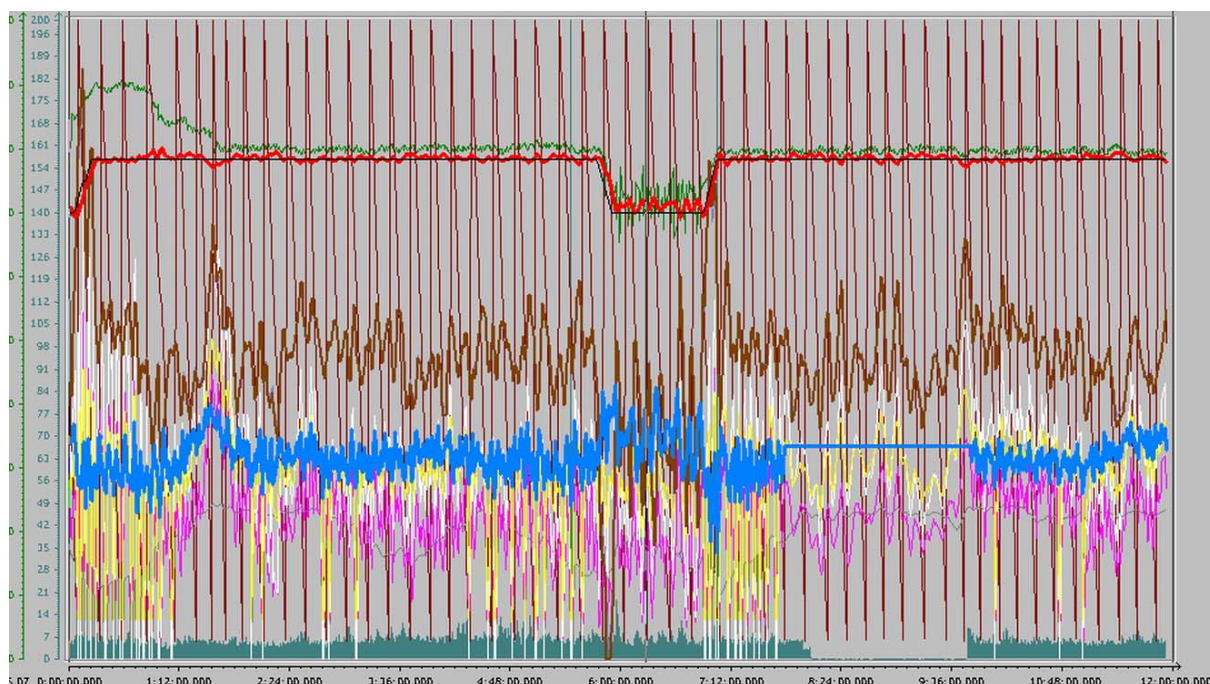


Fig. 5.1: Comparison of old and new steam values by time charts

A more reliable illustration of the relations can be delivered by the presentation of the deviation of the actual plant data (i.e. steam flow) from the set-point.

Fig. 5.2 shows the deviation of the actual value of steam production in relation to the set point in percent for month April 2007 on basis of 5-minutes-actual-values. It is obvious that the new combustion control system has a much less deviation. More than 95 % of the values of the new combustion control system are in an interval $2\sigma = 2,6\%$ while the old system has a standard deviation of 7,6 %. To demonstrate that there is a fluctuation in different months, the data of an extremely good month with the old combustion control are shown in Fig. 5.3. In May 2007 the standard deviation for the new system is 3,3%, for the old CC 3,8 %. The comparison of different months leads to medium standard deviations as:

- new CCS: $\approx 3\%$
- old CCS: $\approx 6\%$.

Although the old CCS is - compared to other plants - a quite good system, the new advanced combustion control system delivers excellent results concerning the steam values, that leads to a higher efficiency because of operating closer to the maximum load, and is an impressive improvement of the stability of the combustion, which can avoid damage to the plants components. Additionally a positive impact can be given to environmental aspects.

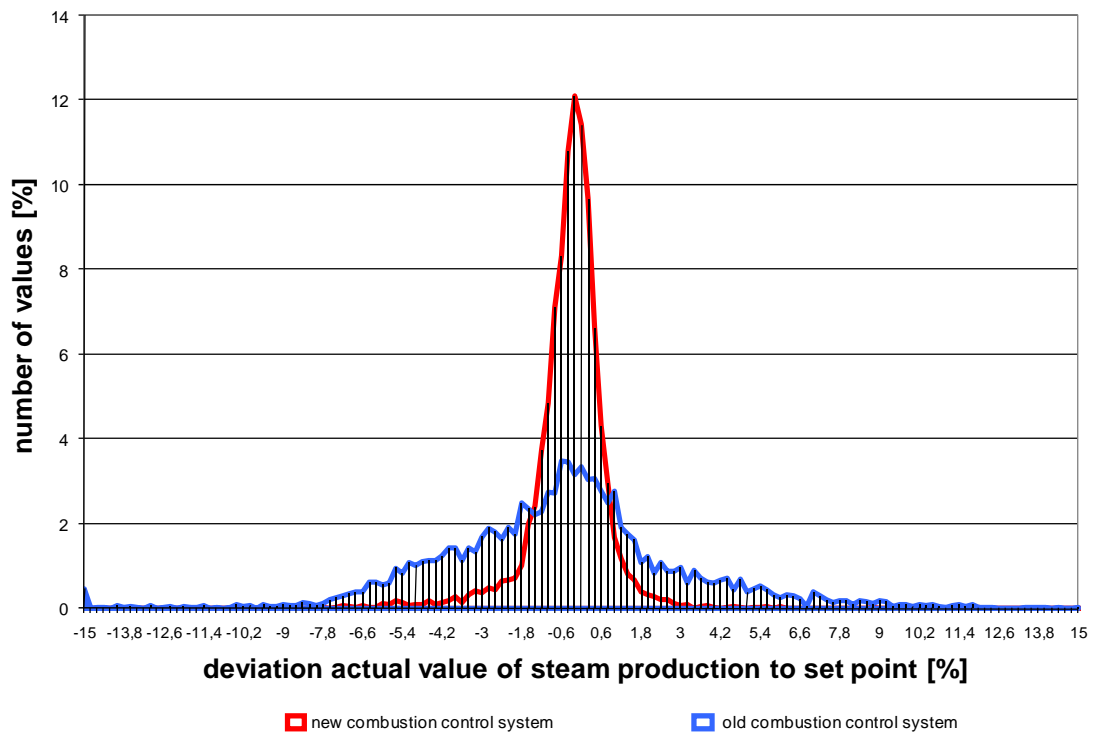


Fig. 5.2: Comparison of old and new steam production values by a deviation function as deviation of offset from steam production in April 2007

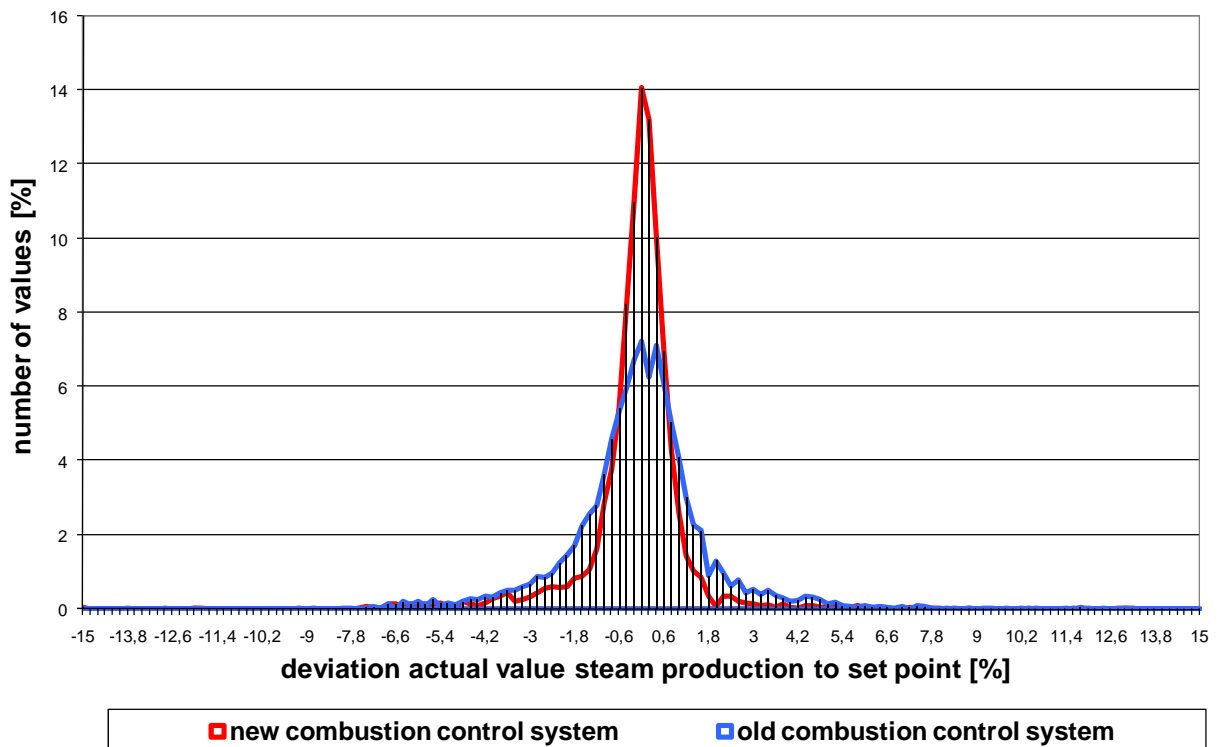


Fig. 5.3: Comparison of old and new steam production values by a deviation function as deviation of offset from steam production in May 2007

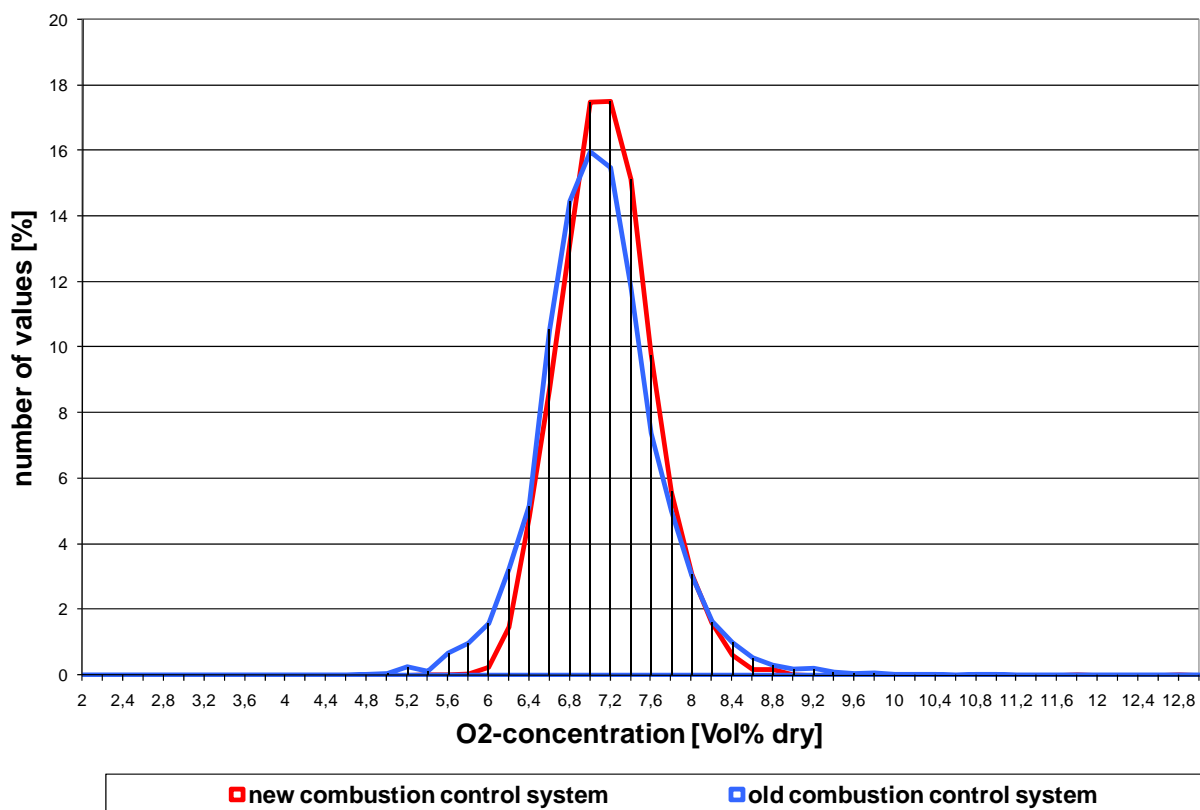


Fig. 5.4: O₂ concentration: old CC compared with new CC

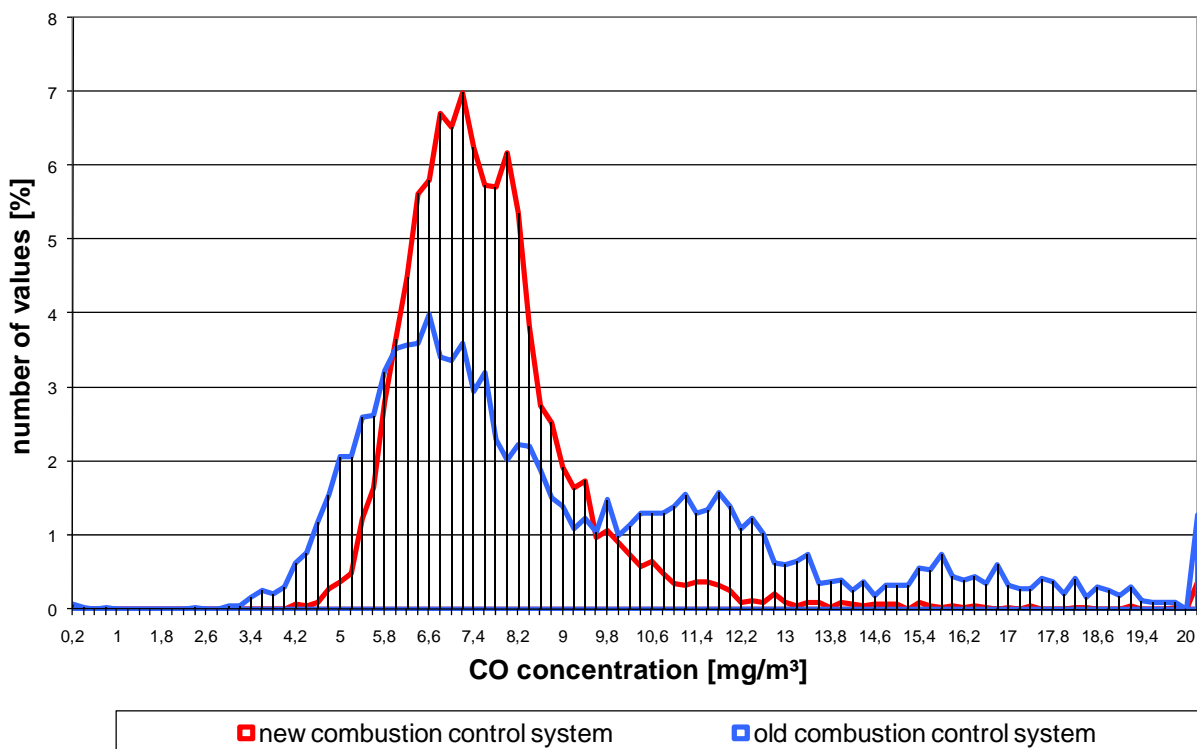


Fig. 5.5: CO concentration: old CC compared with new CC

While the oxygen content (Fig. 5.4) in the flue gas does show a slight advantage only for the new system referred to the old one, the CO content (Fig. 5.5) is decreased by about 15 %. The average in the old system was 9 mg/m^3 , the new system releases 7.7 mg/m^3 (all concentrations referred to standard conditions and 11 % O₂).

This environmentally issue was not the primary aim of the project and was not really expected. Nevertheless this is an interesting effect, which shows the advantage of the new advanced combustion control system. It can be stated, that the project has brought an economical and ecological improvement for the plant.

6 SUMMARY AND OUTLOOK

The old PID combustion control system of line 11 of the GKS waste-to-energy plant was replaced by a new advanced combustion control system. The new system has a complex but clearly arranged systematic with high flexibility to implement further modern control variables.

The results of the new combustion control system, compared as the deviation of the actual values to set point values, are impressive good in relation to the old system and in contrast to other plants. The average deviations for the steam production are:

- new CCS: $\approx 3\%$
- old CCS: $\approx 6\%$.

which is an improvement of about 100 %. The enhancement of operation allows on the one hands side a closer operation to the maximum load and on the other hands side a more gentle operation of the plant. The second point can for example lead to a decrease of corrosion, what has to be investigated in the future.

Beside the improvement of operation, environmental aspects are gained. The CO content in the flue gas was reduced by about 15 %.

All in all the new advanced combustion control system has stated its economical and ecological improvements. The system decision can be recommended to other operators.

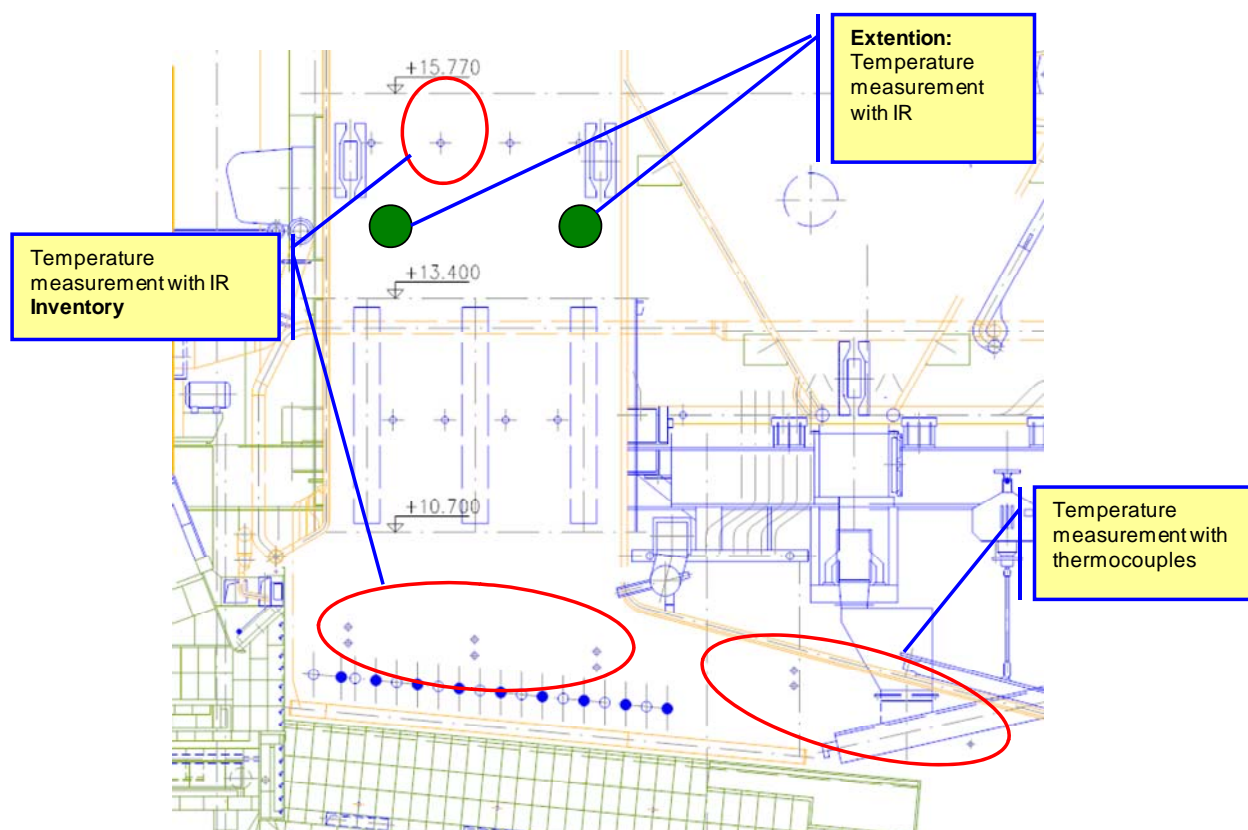


Fig. 6.1: Extended measurements for optimisation of the controller

Nevertheless, also an excellent system can be improved.

Sometimes there is a situation during operation in which no precise decision of the status of combustion can be made. When the steam flow decreases it is not clear if there is enough fuel on the grate or if the fuel on the grate was not ignited, respectively the fuel was too wet. Then the control system has two possibilities: to convey more fuel on the grate (1st case) or to ignite the fuel on the bed by preheating the primary air or by distributing to primary air. In these cases temperature measurements near the front and rear wall in the lower 1st pass can give an indication of the cases. This will be implemented in the coming future.

To get further information of the fuel bed a physical model was developed. This is able to calculate the height of the fuel bed on the basis of input data as the manipulated variables. The integration into the new combustion control system has to be realised as well as the validation of the calculation will be aim of the deliverable 2.2.4.

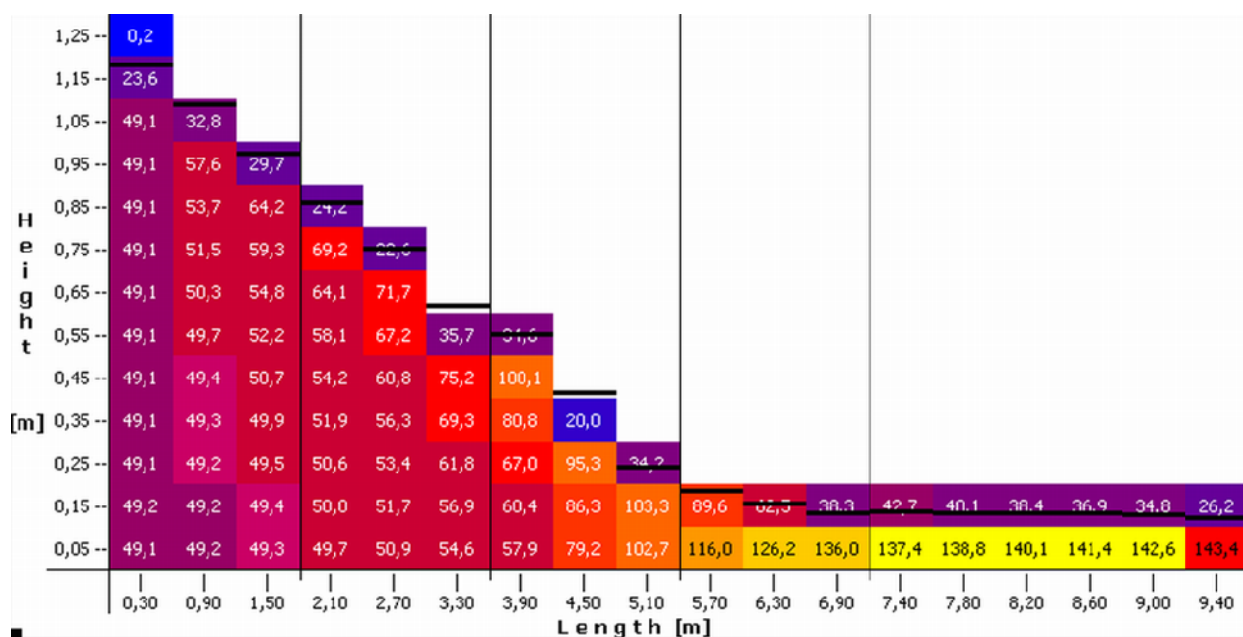


Fig. 6.2: Height of the fuel bed calculated by a physical model

To sum up the results of this task it can be stated that the installation of the new advanced combustion control system was economically and ecologically very successful.