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RDF Waste to Energy Plant
2x25 MWth; 13,6 MWel

TECHNOLOGY DESCRIPTION

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1. Operational plant data

1.1. Basic design data

- Fuel type: RDF from MSW and CW
- Average calorific value of fuel: 12 MJ/kg
- Fuel particle size: up to 80 * 80 mm
- Moisture content in fuel: max. 25 %
- Ash content: approx. 10-15% (depending on fuel)
- Chlorine content: max. 0,6 %w
- Fluorine content: max. 0,1%
- Sulphur content: max. 0,5 %w
- Nitrogen content: max. 0,8 %w
- Total fuel burning capacity: approx. 120.000 t/a
- Steam production of the boiler: 2 x 26,8 t/h
- Steam parameters: 76 bar, 430° C
- Power production: 13,6 MWel
- Annual operation: 24 h/day, 7.800 h/year
- **R1 COMPLIANT PLANT**

1.2. Operating conditions of the plant

- Continuous operation at full load;
- Extraction of the useful energy as stated;
- Required quantity and constant composition of waste;
- Presence of professionally trained operators;
- Normal supply of all additives, water, gas/oil, electricity

1.3. Emission data

Grid Powr guarantees the following emissions values under Directive 2010/75 EU as well Best available techniques BAT, Conclusions Commission implementing decision (EU) 2019/2010

As stated Emission values will comply also with new values expected in new BREF/BAT document.

Concentrations are adjusted to 11%$_v$ O_2–content (volumetric) in gases.

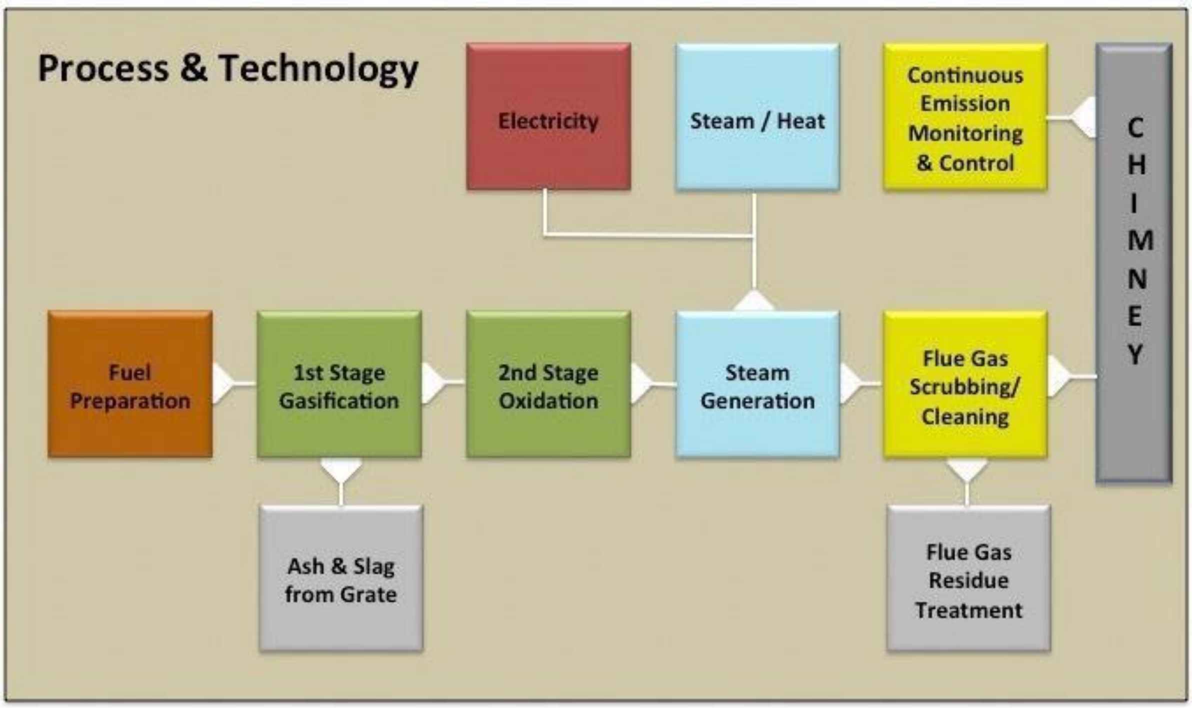
Emission	Half-hour meanvalues mg/Nm^3	Daily mean values mg/Nm^3	Design point mg/Nm^3	Expected values mg/Nm^3	BAT / BREF values mg/Nm^3
Dust	30	10	**5**	≤2	2-5
Total organic carbon TOC	20	10	**3**	≤1	1-3
Hydrochloric acid (HCl)	60	10	**5**	≤2	2–6
Hydrofluoric acid (HF)	4	1	**0,5**	≤0,1	<1
Sulphur dioxide (SO2)	200	50	**20**	≤5	5–30
Nitrogen oxides (NO2)	400	200	**80**	≤80	50–120
Carbon monoxide (CO)	100	50	**20**	4	10-50
Heavy metals:					
Hg	0,5	0,05	**≤0,02**	≤0,02	0,005–0,02
Cd and Tl (total)		0,05	**≤0,02**	≤0,02	0,005-0,02
Sb,As,Pb,Cr,Co, Cu,Mn,Ni,V,Sn (total)		0,5	**≤0,05**	≤0,05	0,01-0,3
4As, Cd, Co, Cr or As, Cd, Co, Cr (total)		0,05	**≤0,05**	≤0,05	
Dioxins and furans		0,1 ngTE/Nm3	**≤0,04**	≤0,02	0,01–0,04

2. Technology description of the waste to energy plant

2.1. Technology

The two-stage process described hereinafter complies with the Directive 2010/75 EU **Waste Incineration Directive (WID)** and **Integrated Pollution Prevention and Control Directive (IPPC)**, and is achieved through the following steps:

- On-site preparation of fuel (if required), transport of fuel from fuel pit to feeding units (via intermediate storage if required), and feeding of fuel (waste material);
- Heating, drying and gasification of fuel in the primary chamber – formation of the syngas;
- Mixing and complete oxidation of the syngas in the secondary chamber;
- Utilization of heat from flue gases for the generation of electricity and/or required heat/steam;
- Flue gas cleaning/scrubbing in compliance with WID requirements;
- Continuous monitoring and recording of the flue gas emissions for compliance with WID and IPPC directives



2.2. Preparation, storage, transport and feeding of the fuel

Pre-sorted, processed, and mixed fuel is stored in the fuel pit or appropriate fuel storage area, from where it is transported to the intermediate storage (in case of crane transport) and then further to the hoppers of the fuel feeding units positioned above the two hybrid combustion chambers. These screw feeding units provide a continuous and steady fuel transport into the chambers (two per travelling grate). In comparison with discontinuous feeding system (ram feed), the continuous screw feeding system provides a uniform 2 stage combustion of fuel and thereby minimizes the extreme values of CO and TOC emissions (these extreme emission values can be reached if large quantity of fuel is fed in batches, as is the case with ram feed systems).

Feeding of fuel into the gasification chamber begins when the temperature inside the chamber is above 850°C. To reach and sustain this temperature, natural gas or LPG burners are used. If the temperature falls below 850°C, or if emissions exceed the maximum allowed values, the fuel feeding is stopped. Fuel feeding is continuously controlled and daily fuel consumption is regularly recorded.

The system consists of:

- Crane
- Intermediate storage
- Chain and screw transporters from daily storage to the feeding units;
- Feeding units with feeding screws Crane with automatic/manual control
- Crane with support steel structure, automatic/manual controls, visual control, electrical connections
- Intermediate storage used as a buffer and a loading dock for transport of fuel from the pit to the dosing units via crane, complete hydraulic system, package with electro motor, cylinders
- Valves, pressure and level switches, safety system, drainage, housing.
- Crane with automatic and manual control will be fitted in the fuel pit. Crane will transport fuel from the pit into the intermediate storage will serve as a fuel buffer during dosing. Storage area – pit – shall be designed for 3 days of operation at plant’s full capacity, while intermediate storage shall serve as a few hours’ buffer.
- As an option, fuel shredding to required size and metal (ferrous and non-ferrous) separation

2.3. Fuel feeding units

Each gasification chamber has three fuel feeding units consisting of two screw feeders each (six screw feeders in total). Above each pair of screws, a larger but shorter dividing screw is placed at 90° angle, which distributes the fuel equally between the two pairs of feeding screws depending on the level of the fuel in each hopper. Above the dividing screw a cellular lock is installed, which shuts down the fuel transportation system in case of a system failure.

Each fuel feeding screw is equipped with a double safety system, in case of a back-fire:

- Combination of one Pt-sensor and two magnetic valves,
- Water flooding thermostatic valve (in case of a system failure),
- Additional manual valve.

In case of an increased temperature of the housing, the electromagnetic valve is activated first. If the fire is not successfully extinguished the thermostatic valve also opens. For stopping the fire from spreading into the fuel storage, the manual barrier flap is installed.

Fuel dosing into the gasification chamber begins after the temperature in the secondary chamber has reached 850°C as required by the WID. If the temperature in the secondary chamber cannot be sustained for a longer period of time (even with the help of gas/oil burners), the fuel dosing is stopped.

2.4. Gasification unit - (heating, drying, and two stage combustion)

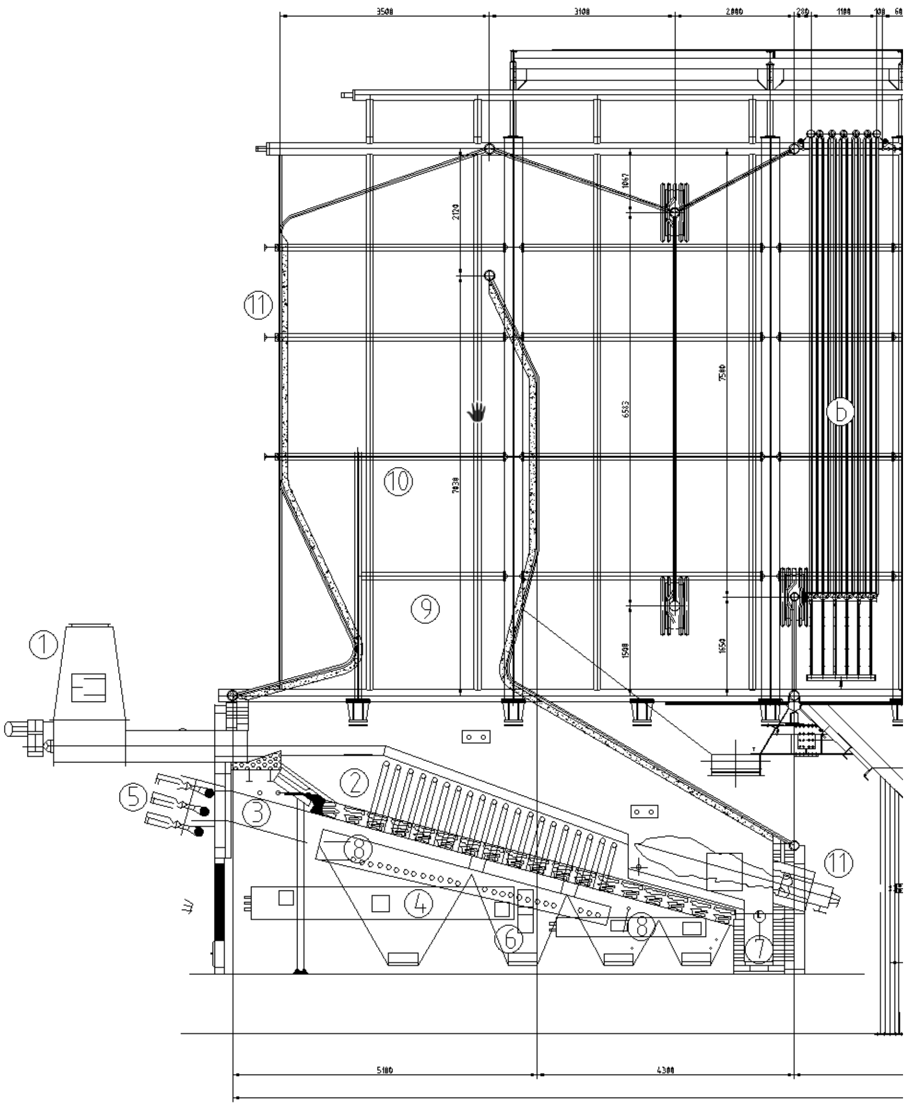
Two stage combustion is a process that converts carbonaceous materials contained within the waste material, into methane (CH_4), carbon monoxide (CO) and hydrogen (H_2) by reacting the material at high temperatures with a controlled amount of oxygen (air). The resulting gas mixture is called syngas and can be further used as a fuel.

In the gasification chamber a temperature of 500–850°C is required (depending on a type and quality of fuel). Sub-stoichiometric conditions must prevail within the chamber in order to provide the environment for gasification process. The quantity of primary air must be carefully controlled and regulated in order to provide optimal conditions for drying and gasification of the fuel.

In the secondary chamber (thermal reactor), which is integrated in cladded part of the boiler, careful supply of the secondary air in the mixing zone generates an optimum mixture of air and syngas. In the subsequent zone this mixture is completely oxidised, whereat complete combustion is assured by correct mixing procedure and by supplement of the tertiary air. Gas/oil burners must be installed for preheating of the secondary chamber during start-up and for sustaining the minimum required temperature as required by IED.

2.4.1. Gasification unit

A Grid Powr design – triple 3-stage stepwise moving grate system – is a foundation of the process. It is designed with a proper, in practice verified inclination of 35/15°, and is divided into three sections. In the first section fuel is heated and dried with a help of recirculation flue gases, which increase the temperature of the fuel and thus prepare it for first stage of combustion. On the second section of the grate fuel is ignited and gasified, whereas syngas is produces due to sub-stoichiometric conditions. Produced syngas is composed mostly of H_2, CO and small amount of un-oxidized hydrocarbons, plus water vapor, N_2 and other elements found in the air or fuel. Such composition of syngas has a rather high calorific value and allows subsequent oxidation process to take place in the secondary chamber. The last section of the grate is where a burn-out and a complete oxidation of the solid fuel takes place and thus minimizing the TOC content of the residue.



Drawing is symbolic.

Main parts:

1. Dosing device
2. Moving grate
3. Water cooled grate carriers
4. Grate carriage
5. Hydraulic drive of the grate
6. Screws for ash removal under the grate
7. Water cooled screw for slag removal
8. Intake of the primary air
9. Intake of the secondary air
10. Intake of the tertiary air
11. Gas/oil burners in the primary/secondary chamber

Gasification chamber is internally coated with high-temperature resistant refractory. On the outside it is an water-cooled membrane walls. Grate must be of proper thermal and chemical resistance, which is achieved by a chrome-based alloy. Cooling of the grate is achieved by blowing primary air and recirculated flue gas across their surface – this assures a longer lifetime of the grates.

At the bottom of the chamber is a hydraulically operated step grate, designed to push the fuel forward into the last ash trough equipped with a water-cooled screw. Speed of the step grate is adjusted according to the fuel combustion algorithms. Moving of the grate is programmed in order to achieve optimum dwell time of the fuel inside the gasifier and thus also a high efficiency of the two stage combustion process.

At the end of the gasification chamber a screw-type ash transporter is installed, which is used for the transport and cooling of the incombustible parts (residual) in the fuel. Amount of ash and slag depends on the fuel. Screw transporters are water-cooled. Transport system also includes inclined screw transporters along the gasifier and transverse screw transporters, which push ash into an ash container.

Primary air is supplied by a computer-controlled variable-speed drive fans into the separate cone-shaped sections below the grates and into the side walls of the primary chamber. To prevent excessive temperatures in the primary chamber (grate) the recirculation of flue gases is utilized.

In the gasification chamber process takes place due to the oxygen-poor (sub-stoichiometric) environment, which produces syngas (organic gases) at temperatures between 600 and 850°C. The temperature in the gasification chamber is constantly maintained within predefined limits by means of a computer controlled automatic regulation of the quantity of the primary air, primary chamber gas/oil burners (at the start-up and in case of poor fuel quality only), heat recovery from the flue gases in steam boiler, and recirculation of flue gasses.

2.5. Flue gas treatment and monitoring

Flue gas cleaning/scrubbing systems consists of:

- DeNOx system
  - Recirculation of flue gases to reduce the NOx emissions
  - SNCR system for lowering the NOx emissions
  - SCR system for lowering the NOx emissions
- Multicyclone for dust separation
- Dry flue gas scrubbing using bicarbonate or lime and activated carbon
- Bag filters for reducing dust particulate quantity in flue gases

2.5.1. DeNOx

Nitrogen oxide emissions are regulated, with acceptable concentration levels set to 200 mg/Nm3 but plant is designed to lower the emissions below 80 mg/Nm^3.

Achieving values below 80 mg/Nm^3 limit is achieved with primary control measures of controlled two stage combustion and use of SNCR technology (Selective Non Catalytic Reduction) with injection of ammonia (ammonia solution or gaseous ammonia) or urea solution into the hot flue gasses.

Further lowering achieved with using of SCR technology (Selective Catalytic Reduction) with injection of ammonia (ammonia solution or gaseous ammonia) into the hot flue gases.

CAPEX and OPEX for SNCR technology are significantly lower than those of SCR technology, but SNCR technology has technological limitation for lowering NOx.

With this design to have primary measure of controlled combustion, coupled with SNCR system as secondary measure and much smaller SCR (smaller catalyst) on the tail for final NOx lowering, it had been made possible not to increase CAPEX significantly and to keep OPEX at acceptable level.

2.5.2. Acidic particles (HCl, HF, SOx), PCCD/DF, PAH, PCB and Hg (heavy metals)

Prior the filter bicarbonate or lime is injected in order to enable the neutralization of SOx, HCl and HF acids in the flue gases. The advantage of a dry flue gas scrubbing procedure is that there is no wastewater, which is a product of the wet scrubbing procedure. Wastewater treatment is complicated, expensive and technologically very demanding procedure. In case of dry scrubbing, bicarbonate or lime powder is metered and injected into flue gas duct, where it reacts with and neutralizes acid gases such as HCl, HF and SO_2. Activated carbon is also injected into flue gases in order to remove any residual PCCD/DF, PAH, PCB and Hg (heavy metals).

2.5.3. Dust - Bag filters

After passing through the boiler flue gases are led into the dry flue gas filtration unit consisting of bag filters with automatic pneumatic blow-down cleaning system. The filter will enable particle emissions to be below 10 mg/Nm^3, which is within IED requirements. Design is for lover values to allow future legislation compliancy for even lower values. Flue gases enter the filter from the side chamber where large particles are eliminated. Afterwards gases pass through the material of the filter where small particles are withheld. Filter bags are supported by the filter cage, which prevents them from deforming due to pressure difference. Filtration residue is thus collected on the outside of the filter from where it is removed by compressed air (4-6 bar) blown down from above and through the filters. Dust is collected at the bottom of the filter chamber. Cleaning of filters is performed during the operation. Below the filter a cell dosing device with a cell valve are installed which prevent the circulation of secondary air.

2.5.4. CEMS

The continuous emission monitoring system (CEMS), which is required by IED, monitors the following parameters:

- carbon monoxide content (CO)
- nitrogen oxides content (NO)
- oxygen content (O2)
- sulfur dioxide content (SO2)
- hydrochloric acid content (HCl)
- hydrofluoric acid content (HF)
- organic carbon content TOC
- moisture in flue gas content
- dust content
- temperature of the flue gas
- absolute pressure of the flue gas
- volume flow of dry flue gas

On the stack, additional ports are installed for periodic independent measurements.

2.6. Boiler

Boiler is producing high pressure superheated steam. Design is natural circulation, water tube boiler with steam reheat superheater.

Boiler plant consists of:

- Feedwater tank with deaerator,
- Feedwater pumps,
- Boiler water conditioning system,
- Economizer,
- Drum,

- Membrane walls,
- Evaporator packages,
- Superheater packages (SH 1, SH 2 and SH3) with intermediate coolers,
- Reheat superheater (SH 4),
- Internal and external boiler piping,
- Water and steam quality monitoring system,
- Safety, measurement and control equipment (safety, manual and actuated valves, steam traps, measurement (pressure, temperature, flow, level, conductivity...),
- Fly ash cleaning system (hammering and soot blowers),
- Deashing system,
- Flash steam system.

In feedwater deaerator, water is heated to 105°C with low pressure steam from turbine uncontrolled extraction and boiler flash tanks to remove gases from the feedwater. In the feedwater tank pH correction and oxygen scavenger are dosed.

Feedwater pumps pump the water through the economizer, where it is preheated, to boiler drum. Drum water level is maintained within narrow level via boiler feed head (set of actuated control valves).

Downcomer boiler piping distribute the water to membrane walls and evaporator package where saturated steam is produced.

Mixture of steam an water is separated in the drum and steam goes to superheaters SH 1, SH 2 and SH3 with intermediate cooling for temperature regulation.

High pressure superheated steam (76 bar(abs) and 430°C) from the boiler goes to turbine. In the turbine HP steam passes through HP part of the turbine and exits the turbine at around 33 bar(abs). Whole amount of the turbine is lead through the SH4 where it is heated again to 430°C and returns to the turbine.

2.7. Turbogenerator set (TG-Set)

2.7.1. Turbine and generator

High pressure superheated steam (76 bar(abs) and 430°C) from the boiler goes to turbine. In the turbine HP steam passes through HP part of the turbine and exits the turbine at around 33 bar(abs). Whole amount of the turbine is lead through the SH4 where it is heated again to 430°C and returns to the turbine.

Steam further expands through LP part of the turbine to deep vacuum (0,2 bar(abs)). There is uncontrolled extraction around 3 bar(abs) for feedwater tank and other heat consumers.

Steam reheat and construction of the turbine ensures very high electrical efficiency in pure condensation mode.

Turbine is equipped with oil filtration and cooling system.

Generator is powered by turbine and produces electricity at 11 kV level which is then stepped to 33, 66 or 134 kV level depending on the local grid conditions.

2.7.2. Air cooled condenser (ACC)

Exhaust steam from the turbine is lead to air cooled condenser (ACC) to be condensed and returned to the system.

Condensing system has also vacuum plant for extraction of non-condensable gases from the system in order to prevent clogging.

Condensate is pumped and returned to the system.

3. Central control and monitoring system (control and visualization - SCADA)

Due to the nature of the plant's operation, a proper control, regulation and monitoring of the system together with all process parameters is foreseen. The system will regulate and control the whole process of the fuel two stage combustion according to the collected data.

Data that will be collected, monitored and processed in the scope of the control system are:

- Temperature in the primary/secondary chamber and flue gas temperature at discrete places
- Pressure drop of air flowing through the grates and pressure in the primary chamber
- O_2-content at the exit of the gasifier
- Steam parameters (pressure, temperature, mass flow)
- Thickness of fuel material on the grate (visual control – camera)
- Flame form inside the chamber (visual control – camera)

Control interventions of the monitoring system include adaptations to:

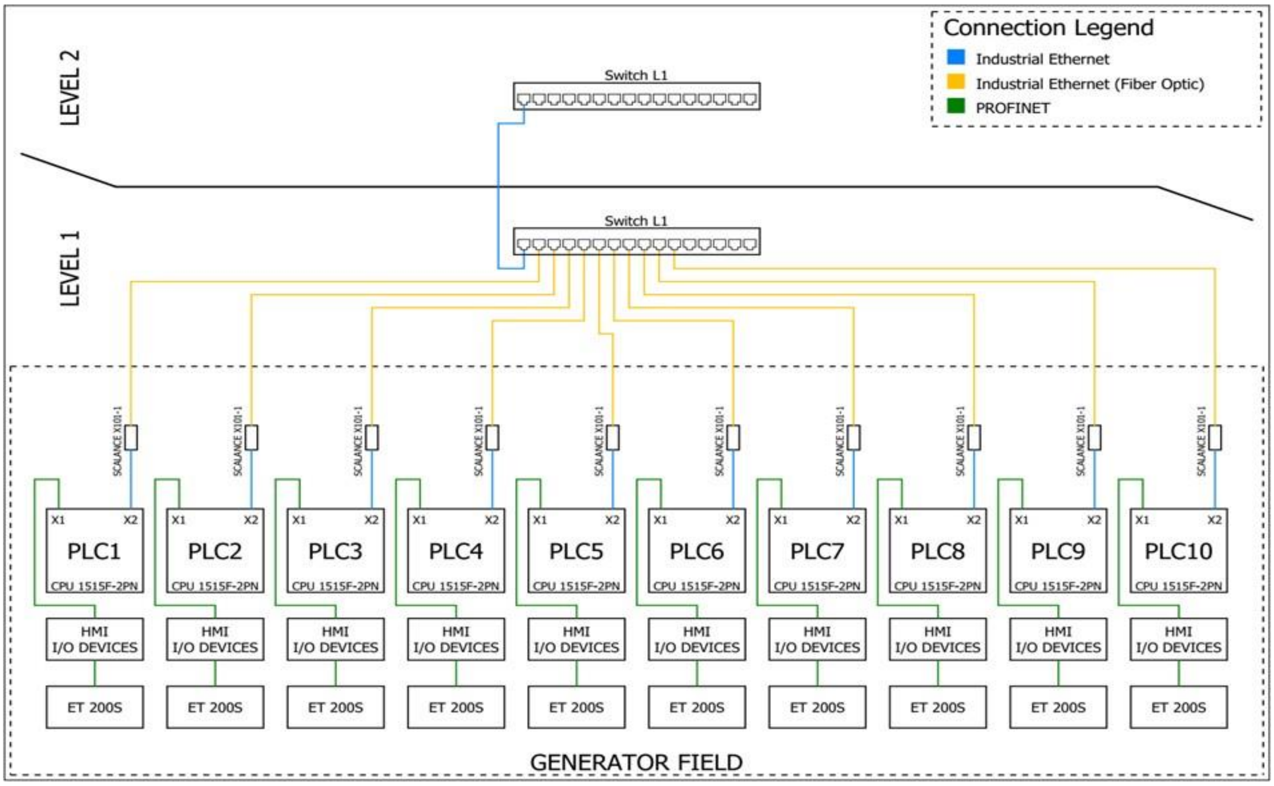
- Fuel feeding rate and quantity
- Frequency and moving speed of the grate
- Quantity and distribution of the primary air
- Quantity and distribution of the secondary and tertiary air, and recirculation of flue gases into the primary chamber
- Ratio of primary, secondary and tertiary air
- Power of auxiliary burners

The entire process is controlled by the highly efficient industrial PLC controlled system. The operation of the plant is automatic, which means that human factor is reduced to minimum (although particular parts of the system can be operated manually or automatically). The procedure is visualized, the operation of the plant and the operating parameters are displayed on the monitor, assuring simple and efficient control of the process. Equipment for continuous measurement of the flue gas emissions is also part of the monitoring procedure of the process. The maximum permissible values of the monitored emissions are defined in compliance with the local regulations, which are currently valid in the area foreseen for the erection of the plant.

The plant is fully automated and the system complies with the stringent air pollution requirements. All integrated motor drives are frequency regulated which is a foundation for qualitative steady state process regulation with the lowest energy consumption. When emission values are close to the maximum permissible values, computer attempts to balance the process. In case the maximum permissible values are exceeded, operation of the plant stops automatically. In case of the emergency alarm visual and audio signal is activated.

All currently valid regulations and stipulations concerning emission values have been taken into account, as well as all relevant safety technical regulations for the design and operation of the plant.

Network architecture of one generator field:



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Network architecture of all generator fields (plant lines)