Block electric heat power + Stand-by power unit
Computer-aided manufacturing and visualisation
Rational electric power use + Energy use control

Sommer-energy

Hauptstr. 52

37355 Deuna

Tel. (03 60 76) 41 02 49

Fax (03 60 76) 41 81 39

k.sommer@bhkw-sommer.de

Plant description of cogeneration unit OEKO 550 G

APO

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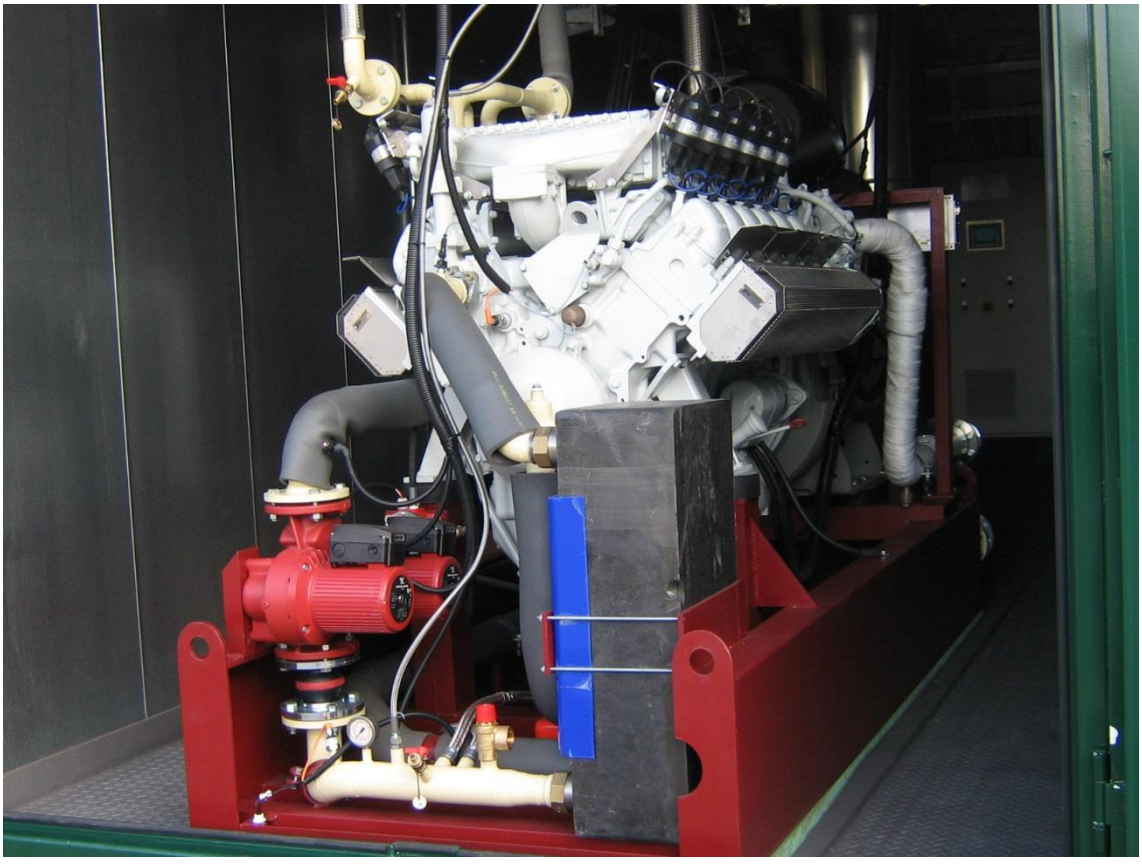
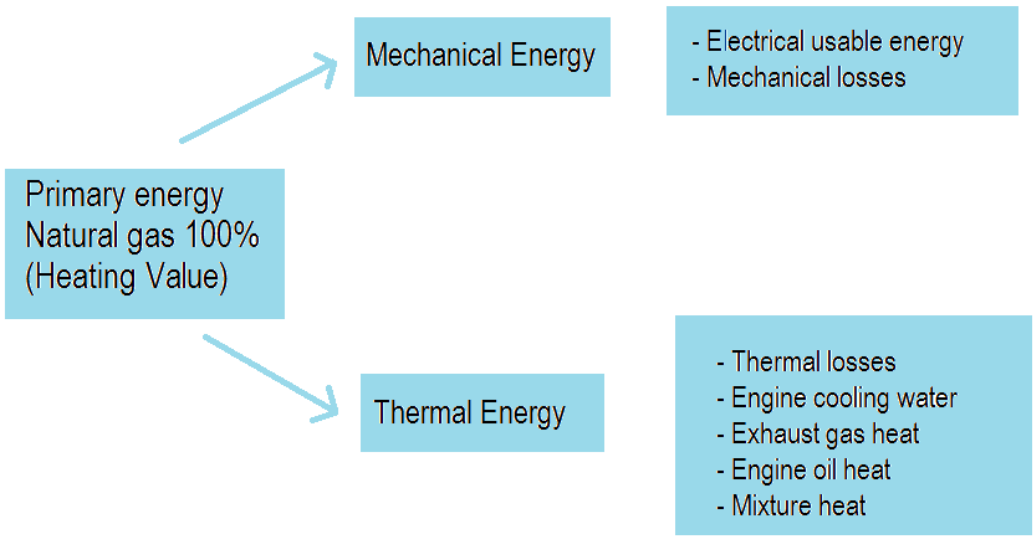


Inhalt

1. General description

1.1. Operation principle

A cogeneration unit is a device ready for connection which produces heat and electric power at the same time. An IC-engine is connected with a synchronous generator with the help of a coupling. This device is built on a frame and fixed with vibration damping fixing. A control unit monitors and regulates the mini-CHP unit. It is possible to adjust power (modulation) in the range of 50 to 100% so that thermal and electrical loads can be compensated. Usually the the supply flow temperature can reach 85 °C whereas the back flow temperature is 65°C. The heat exchanger unit is mounted in the front and bottom part of the engine-base unit. The unit is constructed in a sound-proofing housing for sound isolation or it is placed into a sound-proofing container. Intake and exhaust air is transferred with the help of airborne sound reduced ventilators. To prevent sound transmission due to vibration the unit is connected to the heating system with the help of compensators. Total efficiency of a mini-CHP unit is counted with the sum of electric and thermal usable energy.



1.2. A mini-CHP module basic supply

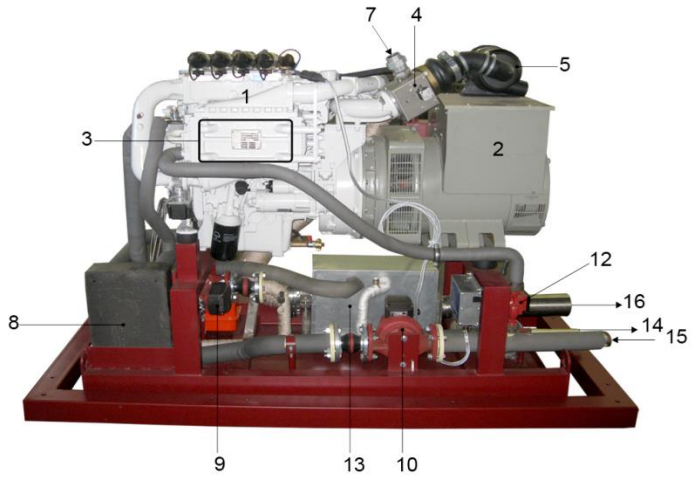
Delivery scope - Standard equipment

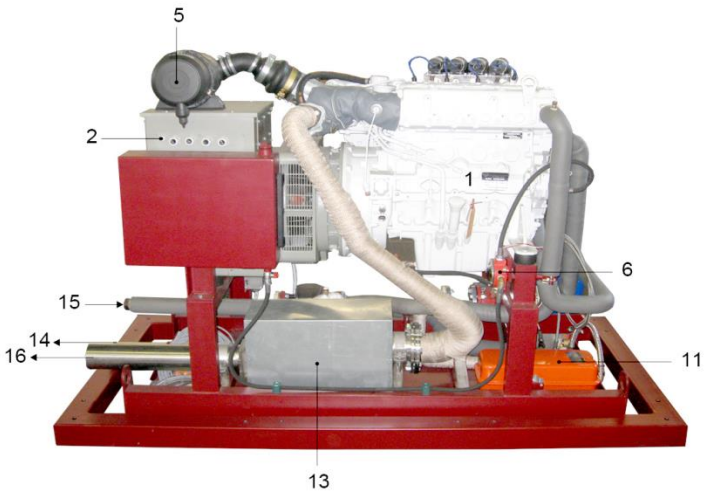
- Otto-Gas industry engine
- Synchronous generator
- Control unit with 10 meters cable to the mini CHP unit
- Heat exchanger unit consisting of cooling water and exhaust gas heat exchanger
- Base frame to mount the engine, generator and heat exchanger unit
- Pumps for the cooling water and heating circuit.
- Lubrication oil level control and supply with an additional oil tank
- Gas control safety system with gas - air mixer
- A starter unit with a network starting device
- Catalysts to reduce harmful substances in the exhaust gas (if nessecary)
- Compensators connection kit (Heating circuit, exhaust gas)
- Sylomer strips (vibration isolation of the base frame from the construction surface)

2. A cogeneration unit construction and its components

2.1. General module construction and characteristics

The following components are supplied with a mini-CHP unit:





01 Engine
02 Generator
03 Mixture cooler
04 Gas-air mixer
05 Air filter
06 Lubrication oil regulator
07 Gas intake
08 Engine cooling water plate heat exchanger
09 Internal pump
10 External pump
11 Expansion tank
12 Mixture cooling pump
13 Exhaust gas heat exchanger
14 Heating supply flow
15 Heating back flow
16 Exhaust gas outlet

The engine and the generator are flanged with each other rigidly via a flexible coupling. This units built on a vibration absorbing base frame. To prevent sound transmission due to vibration the unit is connected to the heating system with the help of compensators. The heat exchanger unit is mounted in the front and bottom part of the engine-base unit. The unit is constructed in a sound-proofing housing for sound isolation or it is placed into a sound-proofing container to provide acoustic insulation. Intake and exhaust air is transferred with the help of ventilators with airborne sound damping. The electrical monitoring and control devices together with the power unit are housed in a control cabinet.

Parallel network mode

In case a cogeneration unit is used in parallel network mode, it is synchronized

with the power network, is switched on and produces electrical power. Power data and efficiency are in accordance with DIN ISO 3046-1 (1000 m above the sea level, absolute air pressure 100 kPa, 25°C and 30% relative humidity).

Power adjustments at ambient conditions are in accordance with DIN ISO 3046-1. The tolerance of specific fuel consumption is up to +5 % at nominal power. The tolerance of usable thermal power is up to 7 % at nominal power. The cooling water data are based upon a 45% share of anti-freeze The data about partial load operations is only for general information, without any guarantee Fuel requirements: this data is counted for the fuel with the lower heating value of 10,0 kWh/norm.m³ and for methane number >80.

Stand-by mode

As the CHP unit is equipped with a synchronous generator, it can also be used at stand-by mode optionally. It is essential at this mode to count the low voltage distribution for emergency power supply (the circuit breaker) If there is an error in energy supply, the cogeneration unit net observer device finds it and turns on the stand-by mode within 15 seconds. Maximum power of the cogeneration unit in the stand-by mode is reduced by 25%,

to have enough energy in case of load fluctuations. In the stand-by mode power is switched on step-by-step (35%- 20%-20%).

If a cogeneration unit works in this mode at any time and any power the removal of heat must be ensured (emergency cooler, a buffer tank).

2.2. Base frame and the pipeline system

On the torsionally rigid base frame, the following components are mounted; Internal-combustion engine (IC-engine), three-phase synchronous generator, engine cooling waterheat exchanger , exhaust gas heat exchanger, cooling water pump, expansion tank for the cooling liquid, heating water system pump, an additional tank for lubrication oil and flue gas cleaning if necessary.

Separate components are connected with each other via pipe couplings and protected from vibrations and expansion forces via compensators. The pipes are isolated as much as possible.

The exhaust pipe is made from stainless steel. The support frame is made from hard standard steel. To decouple the frame and the installation site sylomer strips which are mounted under the frame, are used. The frame has to be constructed on a flat surface and cannot be "fixed."

2.3. Engine

The engine is specially designed as an Otto-gas IC-engine for industrial use. It is developed and designed for permanent operation at 1500 rotations per minute. Oil lubrication is performed with pressure-feed lubrication system. The engine is cooled with the help of cooling water

Manufacturer's information:

Type:	MAN E 3262 LE202
Operation power:	550 kW
Operation mode:	V-Mode
Number of cylinders:	12

2.4. Generator

The generator is driven by a torsinally flexible engine coupling. It is connected to the engine rigidly via bell connection. Electricity is produced by the rotational motion of the generator shaft Voltage and cos -phi controller are integrated in the generator terminal box. Windings and rotor are enclosed in a steel case. The bearing shield is made from cast iron, and bearing balls are covered with permanent lubrication. This is a brushless generator with revolving field "2/3-pitch winding",12-wire version.

The three phase synchronous generator has a cos phi controller which adjusts cos phi from 0,8 to 1,0, an electronical voltage control with a low number of revolutions protection and an additional magnetic permanent excitation device.

Standard 2/3-pitch winding allows to use a generator in parallel network mode with low harmonic content. There is damper winding for parallel operation with other generators. There is a control system for winding temperature."

Manufacturer's information:

Type:	LSA 49.3 M6	Cos-ϕ:	1.0
Product:	Leroy Somer	Construction type:	F
Power:	743 kVA	Altitude of construction:	1000 m above Sea
Number of revolutions	1800 r/min		
Voltage:	400 V		
Frequency:	60 Hz		

2.5. Coupling

The coupling (jaw coupling) connects gas IC-engine shaft with the shaft of three phase synchronous generator. The jaw coupling is made of silicone, it is mounted axially as torsionally flexible, and passed breakdown test. The coupling can stand torsional moment in the range of 40- 1000.000 Nm. The coupling is also radially mountable.

2.6. Engine starter

To start a cogeneration unit it is necessary to use a starter. Here we use a starter with inertial driver 24 V - 6,5 kW, starter battery capacity is: 88 Ah, 24 V. When an engine shaft reaches rotational idle speed 450 r/min, the starter switches off and the engine controls its rotational speed via the throttle valve at 1500 r/min.

2.7. Starting device from network / battery

In the control cabinet of the cogeneration unit, there is a starting device from the network which powers the starter with 24 V. The starting device is switched on through contactor during starting phase. During the normal operation of the cogeneration unit the starting unit is currentless.

If there is an error in network supply, two starter (accumulator) batteries are needed for the starting device. They provide voltage for the starter. It is possible to charge starter batteries with the help of regulating charging device which is installed in the control cabinet High power accumulators produced by Berga Powerblock are used.

2.8. Engine lubrication system

Engine lubrication oil of good quality allows the cogeneration unit to work reliably and continuously.

The IC engine is lubricated by pressure-feed lubrication system.

The used motor oil plays an important role with its lifetime and service intervals.

The whole amount of oil is in the oil sump. From the sump, the motor oil is pumped with pressure through an oil cooler and an oil filter. There is a pressure-relief valve before the oil filter which prevents oil to exceed its maximum pressure. After the oil filter, oil is transferred through different channels to the places which need lubrication - bearings, piston heads and gear wheels. To reduce pressure in crankcase the ventilation system is connected with oil separator which is attached to the combustion air inlet.

The mini-CHP unit is equipped with oil level observer and regulator. Optically the level of lubrication oil has to be seen through the observation window. An oil level controller has an alarm contact. And it is responsible for refilling the consumed motor oil. For that purpose, the cogeneration unit is equipped with an additional oil tank of which volume is adequate at least for the period between two maintenance services.

2.9. Cooling liquid circulation

Cooling liquid circulation forms the primary circulation in the unit which is separated from the water in the heating system with a plate heat exchanger. Water goes through the oil cooler, the engine block and the cooling liquid heat exchanger. The water flows with the help of electric-driven circulation pump. The pump is controlled by the control unit (PLC controller). This control allows the engine to cool steadily after switching off .

Circulation system of cooling liquid includes:	Expansion tank Circulation pump Inlet air valve Pressure-relief valve Thermostat Pressure change indicator

To keep the engine inlet temperature constant, because the amount of water which goes through the engine must be always constant, a temperature controller for the heating system circuit is planned. This is achieved classically by altering the backflow with the help of frequency regulated heating pump. The control is achieved in any case via the contol unit of the CHP unit.

The engine operation is not allowed with too high or too low temperature.

2.10. Water circulation in the heating system

The water circulation in the heating system constitutes the connection of the CHP unit to the building heating. Water in the heating system flows through the secondary circulation of cooling liquid heat exchanger and of exhaust gases heat exchanger and gets the heat from the engine and exhaust gas. The secondary circulation is performed with the help of a circulation pump. The temperature is stabilized with the help of a three port mixer or a frequency-controlled circulation pump. The temperature of the unit is controlled at a constant value in this way and it does not depend on temperature of water in the heating system.

The mounted heat exchanger is in accordance with pressure equipment directive, if necessary. Coupling pipelines and heat exchangers are isolated.

Exhaust gas heat exchanger

The heat produced by combustion is transferred to the heating system through an exhaust

gas heat exchanger. Sommer energy uses 2 types of exhaust gas heat exchangers: classical tube bundle heat exchangers and specially developed plate heat exchangers. The tube bundle heat exchanger has blind flanges at the and inlet outlet openings to enable cleaning. It is made from stainless steel W 1.4301.The welded tube sheets are made of stainless steel 1.4301. The plate heat exchanger consists of copper and stainless steel plates. Due to its construction and design it has a large surface area but small size. The cleaning is impossible.

The exhaust gas heat exchanger is integrated into the heating system. Other variants of connection are also possible. Exhaust system guides: Compensators and piping fittings are welded

Material: W.1.4301

Cooling liquid heat exchanger (Plate heat exchanger)

The soldered plate heat exchanger with foamed isolation is deployed. The heat exchanger has two separate circulation circuits: primary (an engine) and secondary (heating). The heat exchanger aims to transfer heat from the engine to the heating, and engine cooling works in this way. The heat exchanger is connected based on counter-flow (cold water flows towards warm water). The design is carried with a reserve of at least 20%.

2.11. Air filter

This filter is to clean incoming combustion air. The filter is located before the gas-and-air mixer. A dry air filter with replaceable paper filter cartridge is used Maximum negative pressure at inlet should not exceed 30 mbar. the air filter must be changed according to the technical service schedule and must not be used twice.

2.12. Gas pipeline and air-and-gas mixer

The fuel is transferred to the cogeneration unit through a safety gas path. The components of the gas path are in accordance with DVGW to get fiery gas-air mixture combustion gas and air (filtered in advance with an air filter) are mixed in a mixer (Venturi). A throttle valve with a step motor controls the amount of the mixture. Minimal gas flow pressure at the cutoff valve must not be lower than 20 mbar (a gas control system characteristic). EN 746-2 demands leak control of the gas paths which has 1200 kW of nominal thermal power This refers to the electrical power of 500 kW. It is optional for small modules.

Gas path includes the following components:

- Shutoff gas cock (supply limit)
- Gas filter (to keep the following components clean)
- Two gas magnetic valves, or a dual magnetic valve (no-current connection)
- Pressure controller (minimum gas pressure control)
- Constant/zero pressure regulator
- Flexible connection to a mini-CHP module
- Gas and air mixer (Venturi)

2.13. Ignition system

The ignition system guarantees the combustion process of the IC-engine. This system is contactless. The location of every stroke is defined through a device on the cam shaft. The ignition control device calculates the time for each cylinder and controls ignition coils. An ignition spark goes from an ignition coil through silicone ignition cable, plug terminal to the high voltage industry spark plugs.

In the ignition system, it is possible to adjust the ignition timing during the operation. Additionally there is a connector for control and adjustment of ignition from an outside device. Fault message can be transferred through the connector to the outside control system.

2.14. Compensators

To decouple the mechanical vibration of the CHP unit with heating and exhaust systems the compensators are delivered to the assembly site

Delivery items:

- 1 axial compensator for the exhaust gas - flange PN 6, syphon with reducing pipes for welding,

  Material: W 1.4571

- 2 compensators for the heating system pipes - rubber compensators with flanges PN 16 from steel, flange fixing torque 85 Nm
- 1 compensator for gas pipeline - is installed between a gas pipeline and gas-air
- mixer (Venturi) in accordance with demands of DVGW (German Technical and Scientific Association for Gas and Water)

2.15. Electric power meter

Every cogeneration unit has an electric power meter (kWh) with a transformer to measure current power. These measurements are essential for module control and produced energy control. The devices are not calibrated. Optionally it is possible to order calibrated meters.

2.16. Sound-proofing housing (optional)

Sound-proofing housing gives optimal isolation of a cogeneration unit. It consists of separate withdrawable elements, and it is built on the construction area of the unit. The sound-proofing elements are made from galvanized sheet steel and are built as cassettes. The cassettes are filled with rock wool. The inner side is covered with perforated sheet metal. Between perforated sheet metal and rock wool there is nonwoven fabric. The fabric prevents the rock wool spillage. The fresh air comes through an opening in the back side of the sound-proofing housing. There is an opening for outlet air on the roof above the engine. There is also a discharge ventilator. All elements can be easily removed in case of technical service or maintenance.

2.17. Inlet and exhaust systems

Air-supply and discharge ventilation is offered optionally Inlet air comes from the room where the unit is located. It is necessary to pay attention to dimensioning the opening which comes air through. Discharge ventilation is forced with the help of a duct fan. It has to have enough pressure to be able to overcome the resistance of the exhaust unit. Normally a duct noise reducer is attached to the ventilator.

2.18. Exhaust gases noise silencer (optional)

Exhaust gas noise silencer is offered as optional accessory. It is designed specially for application case and for the demanded insertion loss. The silencer combination (absorption + reflection damper) is often used as they reduce especially noise with low frequency.

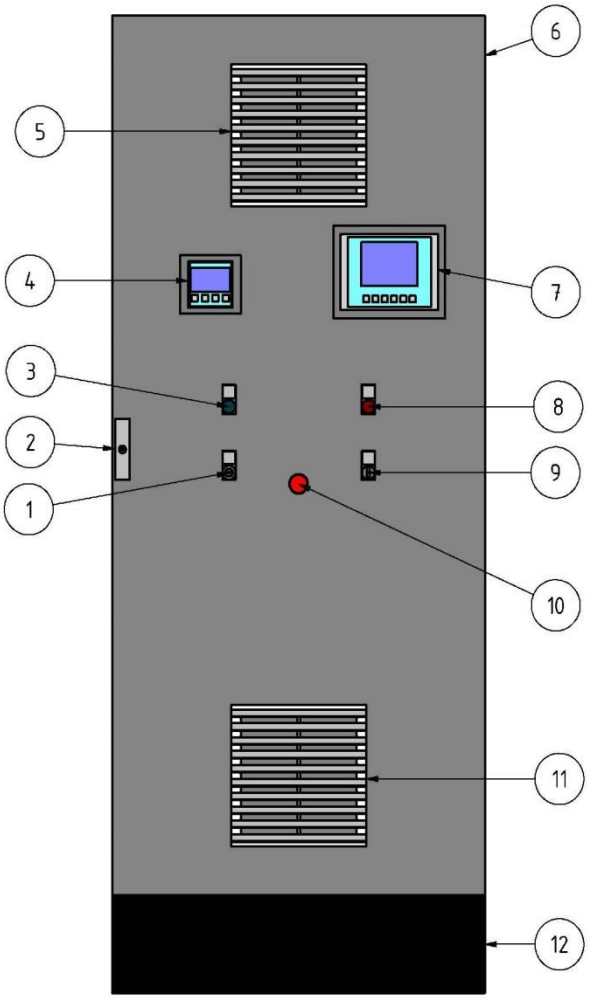
2.19. Control and distribution device

The main task of a distribution closure is to control and regulate the module and

guarantee an economically efficient operation of the unit.

Control Cabinet

- The control cabinet case IP 54, vertical construction made from plate steel with powder spraying RAL 7032, 200mm high
- Includes: control system, power sections, service and protection elements, all wired
- Below electric network connection: 3x400V, N – neutral conductor, PE - protector, 50 hz
- Optional version: special power feed for own use (additional drive)



1. Key switch-board
2. Distribution enclosure lock
3. Switch button “WORK”; on/off control
4. Multimeter (multi-purpose instrument)
5. Inlet air filter
6. Case
7. Operator panel (touch display)
8. Switch button “Error”; confirmation control
9. Manual/automatic switch
10. Emergency button
11. Ventilator
12. Basement

Power section

- Built-in circuit breaker: power protection and generator protection switch with electronical actuating system
- Thermal overload protection of the generator with adjustable operating value
- Selective current cutoff, generator protection from the short circuit with an adjustable time set and operating value
- Immediate current cutoff, generator protection from the short circuit with a permanent operating value
- Optional version: a standardized instrument transformer including a standardized electricity meter

Emergency switch

- Emergency unit shutdown and electrical network power disconnection in case of emergency
- A protective device certified by an international electrical engineering committee “Safety Integrated” (SIL2- IEC 61 508)
- integrated emergency button on the front side of the control cabinet
- Optional version: another outside command device in the safety circuit

Network protection

A certified network decoupling switch controls voltage and frequency of the electrical network. The device is dual channel so one error do not cause the loss of protection function.

Protection functions:

Voltage drop protection	U <
Voltage rise protection	U >
Voltage rise protection	U >>
Frequency drop protection	f <
Frequency rise protection	f >

Limiting values are set in advance. Limiting values can be changed if there are any changes of the set values.

"All settings can be protected with a code and/or sealing."

There is a test protocol and compliance assessment for connection to low-voltage network (VDE AR-N 4105 (the Association of German Electrical Engineers)) and to medium-voltage network (BDEW-instruction).All devices integrated into the coupling protector are tested and approved by experts as reliable.

It can be shutdown at current asymmetry >30% as well.

Synchronization

The synchronizing device compares network and generator voltage for differences in voltage, frequency and phase position. The connection is possible after all synchronization conditions are fulfilled. The device is also designed for harsh service for highly disturbed network.

- Fully-automatic synchronization to network
- A wide range of testing functions against incorrect synchronization
- Protection against generator reverse power at synchronization
- Lead time 10 - 250 msec (to be adjusted)
- Maximum frequency difference 0,15 - 1 Hz (to be adjusted)
- Maximum voltage difference 2 - 10% (to be adjusted)

Control elements on the front side (example)

7“ Colour display

- Visual image of the process on the display
- Intuitive operation with the help of a touch display and functional buttons
- All errors and disturbances can be seen as a text

Control

Module concept of control and regulation based on an internationally recognized automation operating system SIMATIC S7 (SIEMENS)

- Interface: Ethernet TCP / IP; Profinet optional: Profibus; IEC 60870-5-104-Slave, others on demand
- Easy integration to a local customer network, to parent energy system or control system.

Control functions:

- Engine control
- Generator control
- Network control
- Rotational speed control
- Power control
- Lambda control
- Engine temperature control
- Additional drivers control
- Optional: registration of secondary characteristics (electric power, heat, gas)

Power supply of auxiliary drives (gas valves, ventilator, inside pumps, outside circulation pump of a heating system) are in the control cabinet. Optionally, emergency cooler and the other heating regulations or controlling functions can be implemented.

An electric multimeter connected through a local network is located on the door of the control cabinet and allows to control efficiently the quality of the energy produced by a cogeneration unit, to distribute network and a cogeneration unit load, and to control energy consumption by consumers if there is a lack of it. It is possible due to: Registration and control up to 50 measures, such as voltage, the strength of current, power, electric energy, frequency, cos-ϕ with maximum, minimum and average dimensions.

Process visualization

The process visualization software „SIEMENS WinCC-flexible-Runtime" is set on the customer's PC with the internet connection and is connected through local network to the cogeneration unit control system.

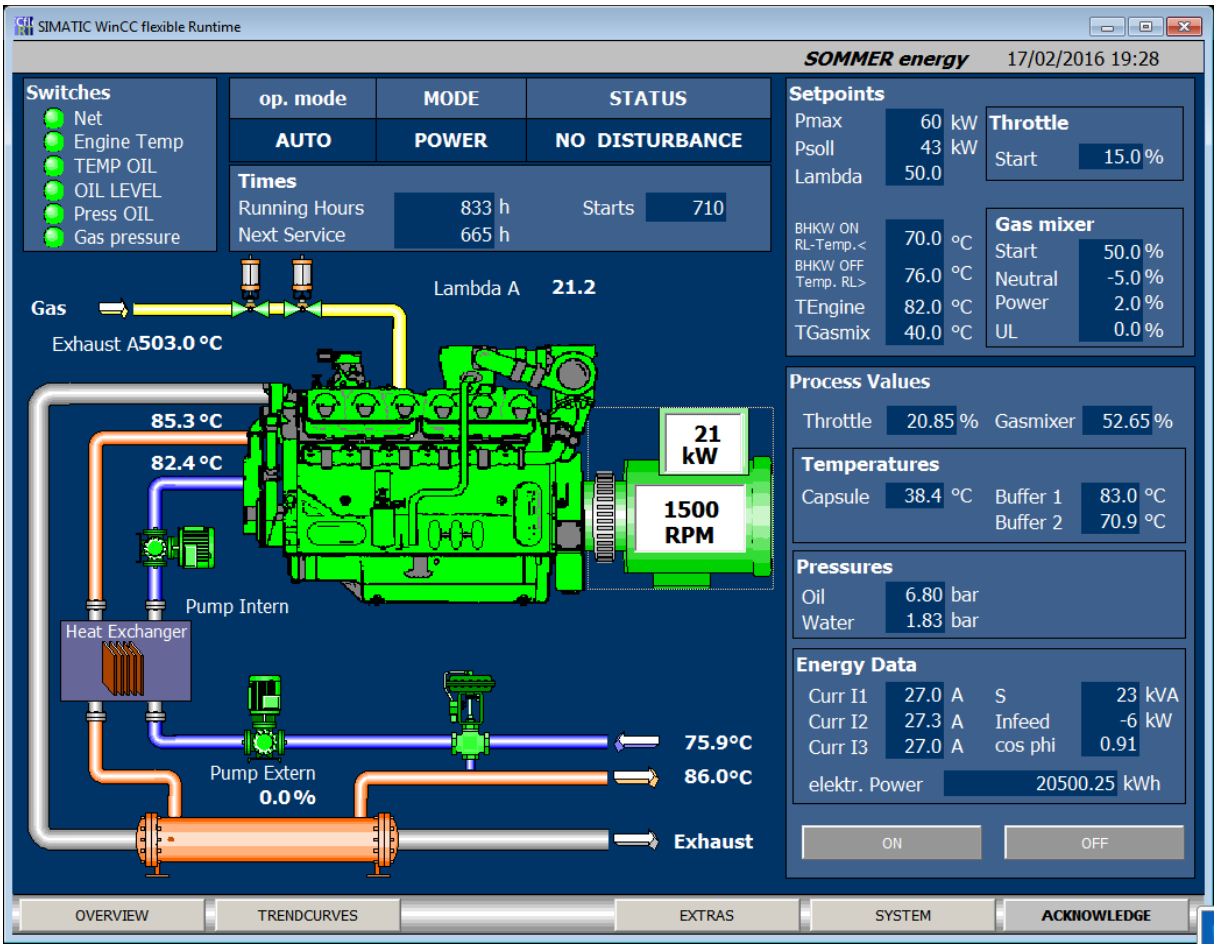
The software is based on the following operation systems:

Windows XP Professional

Windows 7 Professional or Ultimate

Alternatively the access to control system can be provided through VPN tunnel. At this case remote control is possible. It allows to reduce idle time, to interfere in case of failure and to adjust a unit remotely for a more efficient mode.

scheme: remote control screen



Functions:

- Service and supervision
- Process control
- Diagrams, load profile
- Failure messages
- Technical diagnostics and optimization
- Archival storage

2.20. Dimensions/ Technical information

Container Sizes:

Length:	12000 mm
Width:	2950 mm
Height:	3060 mm
Construction:	Isolation is 100 mm thick

Exhaust gas heat exchanger:

Manufacturer:	LUWINOX
Length:	2400 mm
Diameter:	300 mm without Isolation

Exhaust gas noise silencer (optional):

Length:	3200 mm
Diameter	600 mm
Technology:	Absorbtion-reflection principle
Peak sound level:	< 88 dB(A) at the exhaust gas opening
Inlet/ Outlet:	Flange DN 250

Control cabinet

Depth:	400 mm
Width:	1200 mm
Height	2000 mm
Manufacturer:	RITTAL

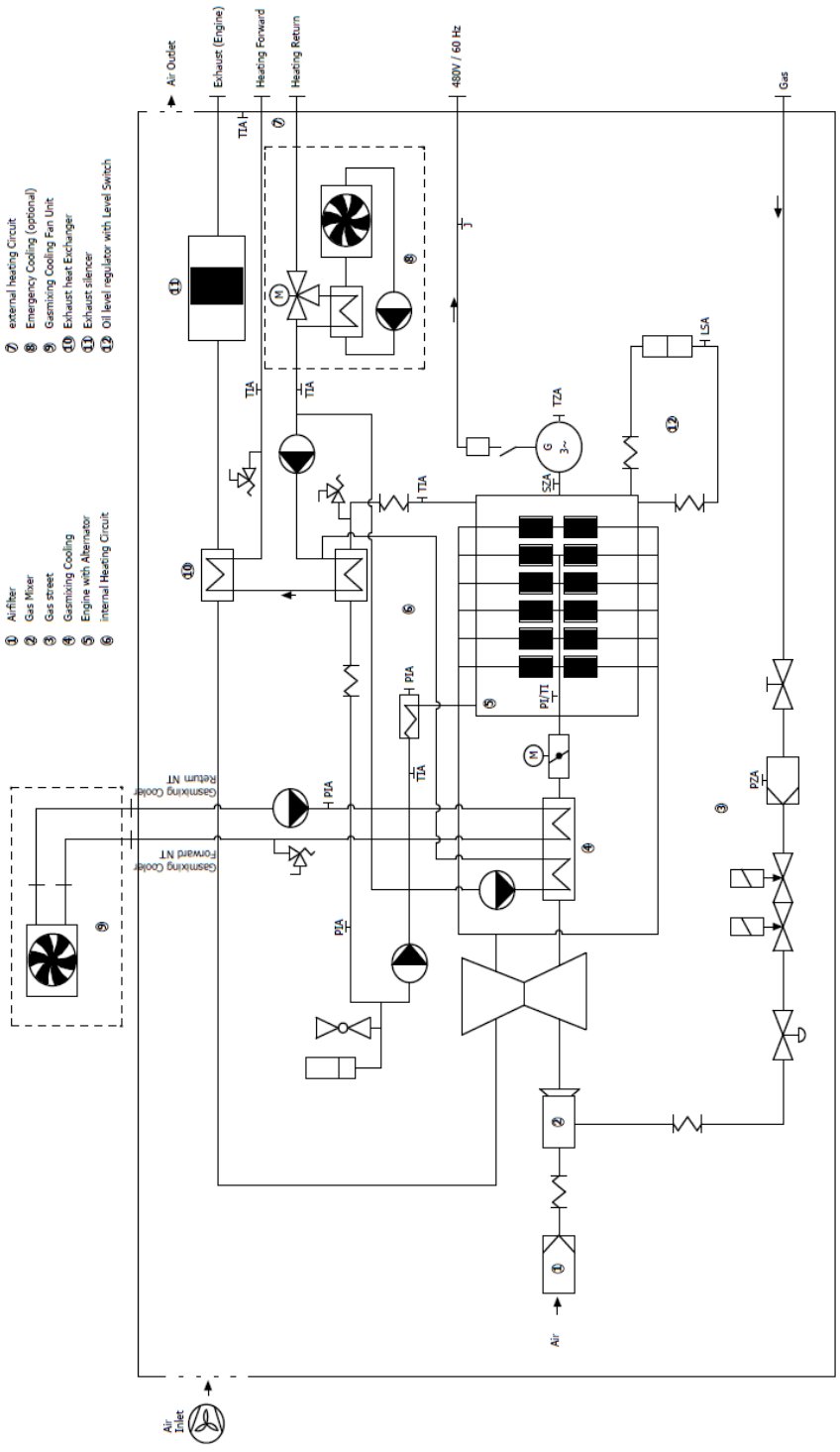
Values of exhaust gas composition

These emission values are based dry exhaust gas at 5% of residual oxygen and after passing through flue gas cleaning

NOx< 500 mg/Nm³ CO< 750 mg/Nm³ lambda = 1,7

2.21. Control equipment

A cogeneration unit has the following main control elements: oil pressure, cooling liquid pressure, pressure in turbocharger, cooling liquid temperature, exhaust gas temperature, heating water temperature, rotational speed, oil level. These detectors connected to a control device and the figures can be seen.



2.22. Operation characteristics

Operation characteristics CHP-Module		OEKO 580G			
Continous Power parallel Mode		Load in %			
		50	75	100	
Electrical power	without overload	275	413	550	kW
Thermal power	Tolerance 7 %	382	573	764	kW
Fuel consumption	Tolerance 5 %	725	1087	1450	kW
Power to heat ratio according to AGFW FW308 standards					0,73
Efficience					
Electrical efficiency		37,9	38,0	37,9	%
Thermal efficiency		52,7	48,7	52,9	%
Total efficiency		90,6	86,7	90,8	%
Power Producing					
Electrical energy (AC current)	Voltage	400			V
	Frequency	60			Hz
Electrical power own consumption (max. incl. Emergency Cooling)		34			kW
Fuels					
Characteristics of fuel, lubrication oil, cooling liquid and hot water					
		Check the up-to-date operation guide			
Filling	Lubrication oil	90			l
	Add. Oil tank	85			l
	Cooling water	50			l
	Heating water	90			°C
Gas connection pressure		25 – 50			mbar
Heat production (Heating)					
Back flow temperature	max.	70			°C
Stnd. tempt. difference	Back flow/ supply flow	20,0			K
Heating water	Volumetric flow	32,8			m^3/h
Operating pressure max		3,0			bar
LT Operating pressure max		2,0			
Pressure losses		0,5			bar
Emission of harmfull substances according to TA-Luft 2002 standards					
NOx-content		< 500			mg/Nm^3
CO-content		< 750			mg/Nm^3
Formaldeyd-content		< 60			mg/Nm^3

3. Operation and technical service

Operation characteristics according to a German industrial directive (DIN) ISO 3046-1

Putting into operation

Only Sommer energy representatives or people certified by Sommer energy can put a mini-CHP unit into operation. Operation parameters are set and checked while putting into operation.

Operation

A cogeneration unit is made for permanent operation (8760 hours per year). Avoid to switch it on and off too often. Minimum working time of a unit has to be not less than two hours after starting.

Technical service

The technical room of the unit must allow an access to do following service works:

- Cranking with special tools
- Valves adjustment, tightening bolts of cylinder heads
- Ignition plugs change (according to manufacturer's engine manual)
- Compression check
- Adjusting and changing the number of rotations - impulse sensors
- Service and exchange of a battery
- Air filter service / change
- Visual examination and tightening of thread, hose and pipe couplings
- Visual control of possible leak
- Control and adjusting of ignition point
- Check and regulation of a step motor of the throttle valve

- Service and testing of engine observer components
- Control of lubrication oil level, oil refill (as described in manufacturer's engine manual)
- Oil filter change (according to manufacturer's engine manual)
- Cooling liquid draining and refilling (according to manufacturer's engine manual)
- Free space for the generator adjustment
- Access to change oil and cooling liquid
- Tightening bolts of cylinder heads
- Maintenance and full repair of an engine will be easier if the access to the following components is planned in advance:

(Disassembling of oil pans without engine removing, disassembling of the generator without the whole block removing, disassembling of inlet and outlet pipes of the cylinder heads, etc.)

Different Types of Maintenances:

E1:

- Leak check
- Check of screw joints
- Change of engine oil / analysis of oil quality*)
- Oil filter change*)
- Gathering the operation parameters
- Start control
- Adjusting/control of throttle valve
- Cleaning/check of gas filter
- Cleaning/check of air filter
- Cleaning/check of impulse sensor
- Check of cooling liquid concentration
- Ignition timing check
- Check of cooling circuit/pressure In the system
- Crankcase pressure measurement
- Exhaust gases backpressure including the catalyst measurement
- Cleaning/check of mixture cooler
- Emissions and lambda check
- Checking of the exhaust unit for outside polluting, and cleaning if necessary

E2

- Leak check
- Check of screw joints
- Change of engine oil/analysis of oil quality*)
- Oil filter change*)
- Gathering the operation parameters
- Ignition spark plugs check

- Start control
- Check of lower pressure at inlet

E3

- Valve clearance check and adjusting if necessary
- Ignition spark plugs change
- Compression pressure measurement
- Adjusting/control of throttle valve
- Cleaning/check of a gas filter
- Cleaning/check of an air filter
- Cleaning/check of an impulse sensor
- Check of cooling liquid concentration
- Check/change of oil seperator
- Ignition time check
- Check of cooling circuit/pressure in the system
- Crankcase pressure measurement
- Exhaust gases including the catalyst backpressure measurement
- Cleaning/check of mixture cooler
- Emissions and lambda check
- Check and calibration of sensors
- Check of screw joints of the exhaust system

R1

- Change of cooling liquid
- **)Crankshaft axial-play measurement
- Exhaust gas turbocharger change
- Change of the exhaust gas pipe

R2

- Change of cylinder liners
- **) Check/change of the piston rods
- Change of piston rings
- Change of cylinder heads

R3

- Engine full repair

**)

G1

- Check of gas pipe components

G2

- Check of gas pipe components
- Check of the gas filters and change if necessary
- Repair of zero pressure regulator / regulator carrier