Automation and Control of Energetic Systems Using Cogeneration Unit in Industry

Michal Špaček and Zdeněk Hradílek

Abstract Recently, we are trying to deal with energy as efficiently as possible. When it comes with nature-friendly technologies and energy saving. One of the possible solutions is to replace the cogeneration unit instead of gas boilers. The gas is burned in a combustion engine which is connected the shaft and an electrical generator that produces electricity. Heat energy is obtained by engine cooling and flue gases. Another possible application of cogeneration unit is overlaying of consumption peaks in power supply network when we are trying to reduce them.

Keywords Cogeneration unit · Electric output · Heating power · Accumulation tank · Energy balance

1 Introduction

One of these energy savings is applied in engineering company in the Czech Republic. Gas boiler and gas burners were replaced by cogeneration unit with storage tank. Thermal and electrical energy are produced by using cogeneration units burning natural gas. To cogeneration unit is connected a pipe for exhausting hot water into the technology and accumulation tank (AKU). Part of the heat (1.3) is thus supplied directly into the technology, and part of the heat (2/3) is supplied into the accumulation tank. The diagram of cogeneration unit technology and accumulation tank is displayed in Fig. 1. The technology uses produced heat is shown in Fig. 2, which shows heat exchanger and heated tanks with chemicals.

Warm water of the main heating circuit of cogeneration unit operates with a thermal gradient of 85/65 °C. For measuring of thermal energy is mounted col-

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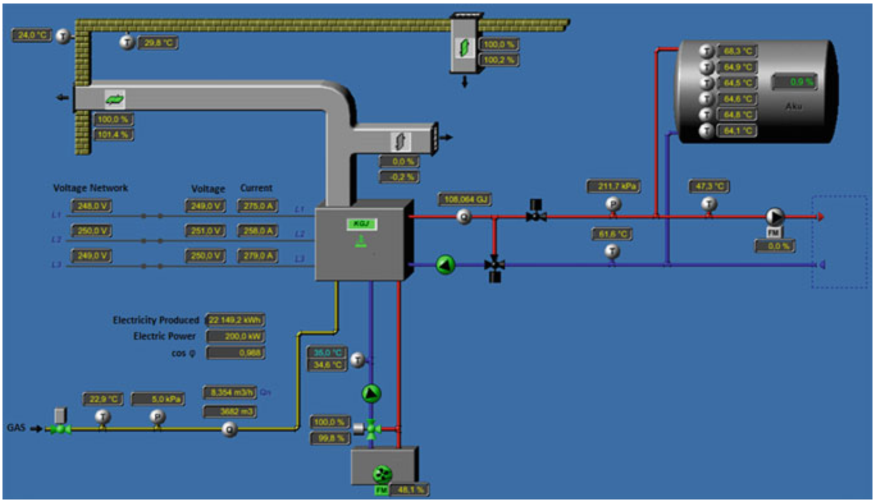

Fig. 1 Visualization of technology of cogeneration unit with accumulation tank and other auxiliary devices

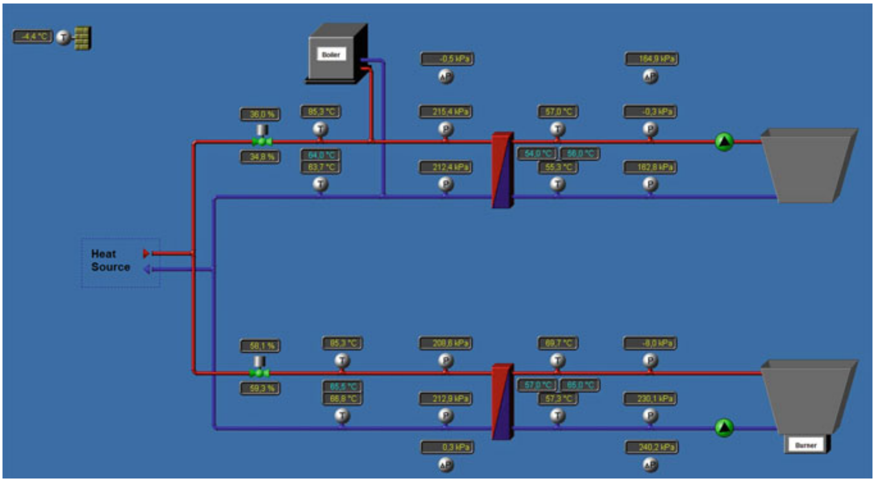

Fig. 2 Visualization of adjacent technologies using thermal energy

orimeter. For accumulation of thermal energy was used accumulation tank with a capacity of 60 m^3. This accumulation tank is thermally insulated.

To achieve greater engine power of cogeneration unit is installed a turbo compressor. Compressed natural gas is cooled using by closed warm water circuit with dry cooler. In the cooling circuit is necessary to maintain the temperature gradient of 38/35 °C.

While designing has been calculated that in the company will be consumed all electrical power. And there will be no supply into the network. For last six months it has started to changeable electricity consumption in the company. Overflows of electricity occurred from cogeneration unit into the network.

The company has requested the reserved power of 0 kW. Against of these overflows company wants to realize the regulation of cogeneration unit to prevent electricity overflows.

2 Technology Cogeneration Unit

2.1 Cogeneration Unit

There are in the company install cogeneration unit with electric power 199 kWe and thermal power 263 kW. Basic data of cogeneration unit are in Table 1.

Important parameter of cogeneration unit is energy balance, constituting a graphical representation of the energy flow. Energy balance shows the conversion of primary energy (natural gas, 100 %) into an electrical and thermal usable energy. Losses which occurs based on energy converting are also shown. Usable electrical energy rise by combustion in a combustion gas Otto engine and its rotary motion is converted in a synchronous generator to a current. Thermal energy rise also by combustion process in a gas Otto engine. Gas Otto engine is operated as a combustion engine with turbo blower and two-stage cooling of the mixture with the air ratio lambda 1.6. It is divided into heat in flue gases, collecting piping, engine block and engine lubricating oil and serves to heating e.g. heating water. The complete efficiency level of cogeneration unit module is sum result of the electric and thermally usable energy, and it is shown in Fig. 3 and Table 1 [1].

The module of block heat power station is unit ready for connection to a source of gas, electric network and heating circuit. It includes an air-cooled synchronous generator to produce three phase power with a voltage of 400 V, 50 Hz. The heating circuit is operated with temperature gradient 85/65 °C. Cogeneration unit module may be operated electrically or thermally, in the operating range of 50 −100 % of rated electric power (corresponding to 60−100 % of the thermal output). Installed cogeneration unit in the company is shown in Fig. 4.

Table 1 Parameters of cogeneration unit [2]

Parameters	Max. electric performance	199 kWe
	Max. heat performance	263 kW
	Engine performance	210 kW
	Fuel consumption	53 Nm^3/h
	Min. total efficiency	89.60 %
	Temperature gradient of heating circuit	65/85 °C
	Max. heat performance	10/50 °C

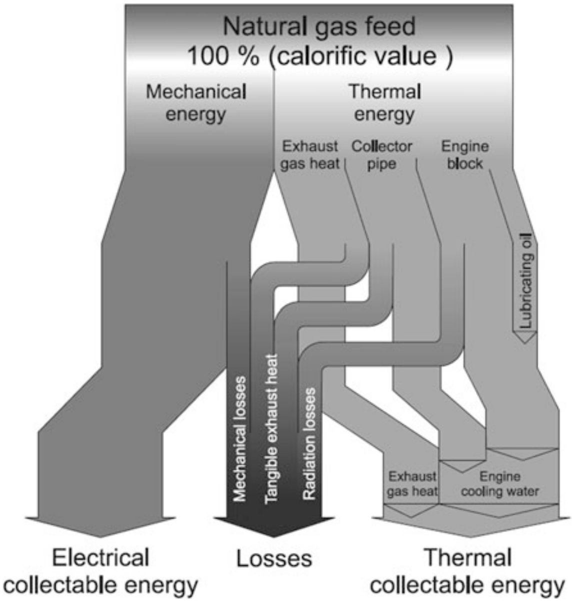

Fig. 3 Energy balance of module cogeneration unit

Fig. 4 Cogeneration unit 199 kWe/263 kW

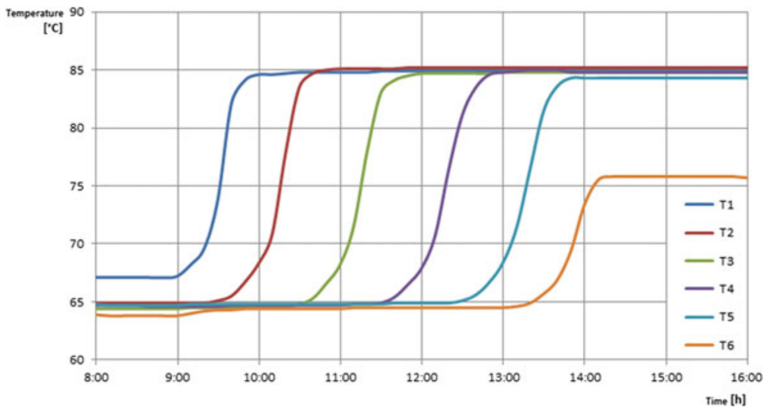

Fig. 5 Charding of storage tank

2.2 *Storage Tank*

Thermal energy is accumulated in a tank of circular cross section 3.40 m and a total length of 60 m^3, with the volume of 7.812 m. The casing of the tank is made from steel with a 100 mm thermal insulation thickness. The tank is in upper and lower part equipped with inputs and outputs for water. The tank is also equipped with six temperature sensors. A temperature gradient of water is 85/65 °C. Inside of the tank are input and output troughs, which ensure uniform inflow of water into the tank to avoid cooking and subsequent mixing of water in the storage tank.

Temperatures are measured with the help of PLC control, which is recorded at 10 min intervals into the PC memory.

Charging process of the storage tank is on the Fig. 5. Temperature sensors with which were recorded waveforms are spread over the entire height of the storage tank. Temperature sensor labeled T1 is located most highly, but temperature sensor T6 is located the lowermost. Temperature sensors T2, T3, T4 and T5 are located downwardly between the sensors T1 up to T6. From Fig. 5 you can see that at 9:00 am cogeneration unit has been activated when the temperature began to rise at the highest point of the storage tank. Depending on the time began to increase temperatures of the individual sensors towards the bottom of the tank. Lowest temperature sensor T6 was recharged only at 76 °C, to avoid overheating of cogeneration unit.

3 Connection of Cogeneration Unit

3.1 *Connection of Cogeneration Unit into the Network*

In Fig. 6 is shown connection diagram of cogeneration unit into the electrical. The company is supplied from a distribution network 22 kV, via two transformers T1

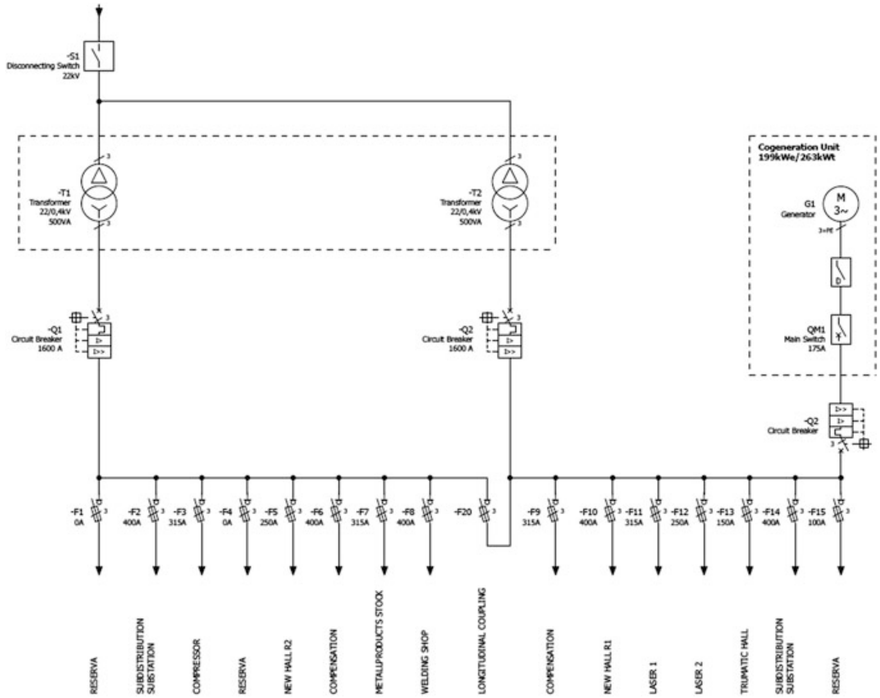

Fig. 6 Mono-polar wiring diagram of cogeneration unit into the network

and T2. Each of them has the performance of 500 kVA. These transformers can operate in parallel or separately. Currently they are working separately, and for their parallel collaboration is used longitudinal fuse switch F20. Transformers operate separately, mainly because of the lasers, which have a very variable consumption from the network, which causes fluctuations in line voltage. For this reason, the company has two types of network, "dirty" and "clean". Clean network is supplied from the transformer T1 on which is connected the lighting, offices and other appliances dependent on the quality of the network. To dirty network (transformer T2) are connected to lasers, welding centers and the cogeneration unit.

3.2 *Control of Electric Power of Cogeneration Unit*

Regulation methods of the cogeneration unit may be large amounts. One of them is continuous regulation that is used most often. Among other control methods belongs jumping method, in which we perfume regulation in individual steps (for example, 50, 60, 70, 80, 90 and 100 % of rated power). For cogeneration units is necessary to keep power control between 50 and 100 % of rated power. Below

50 % of rated power unit has very poor efficiency. The best method of unit operation is at a maximum (100 %) power, in which has the largest ratio produced electricity to heat energy. When designing units from the viewpoint of regulating electric power it is better to propose more units, which would be triggered sequentially according to the desired performance and would be regulated by the rated power. In our case, the unit will be operated at nominal power.

Because unit has an output of 199 kW it falls in the Czech Republic into the category of plants with an output of over 100 kW connected to distribution network. In case of danger and reliable operation of the electricity system is necessary for supervisory control to temporarily restrict or shut down active power supply from the manufactory of electricity [2].

The source must be able to adequately (quickly and accurately) respond to commands from the control room PDS to reduce active power gradually in the mode 0, 50, 75 and 100 % of the installed capacity.

At source is applied smoothly (not stepped) voltage regulation and reactive power (U/Q) according to the dispatcher or by system of automatic control.

To the cogeneration unit is also connected control unit, which provides to control center, operator DS transmission of measuring and signaling about cogeneration unit.

In the Fig. 7, dated 1.7.2015 is recorded cogeneration unit regulation using by RTU control of switchboard emitting signals from the control room. At 10:43 cogeneration unit was turned on when in time 10:48 to nominal value. This cogeneration unit worked in nominal mode until 11:30, when the command came from the dispatcher to reduce the performance of the unit to 75 % of rated power. After two minutes, the unit ran in the 150 kW and in this performance was operated until 12:10, when came the command from the control room to reduce power to

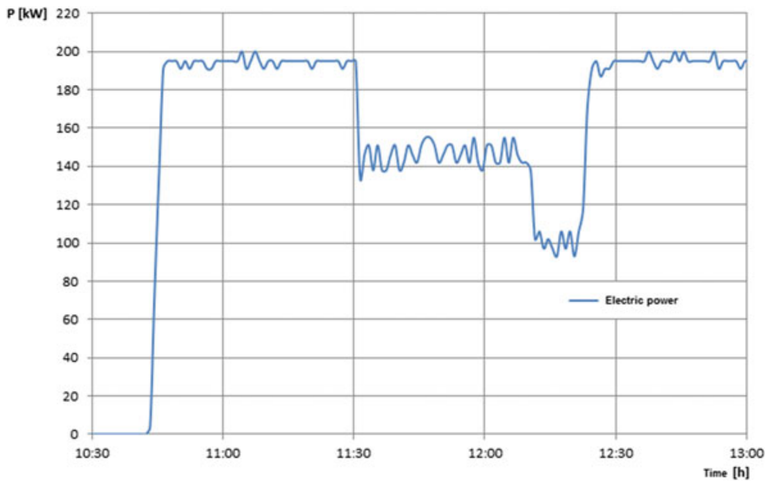

Fig. 7 Performance regulation of KGJ using by RTU switchboard

50 % of rated power (100 kW). Unit ran into this performance for one minute and was operated until 12:23, when came the command for start-up the unit at 100 % of rated power. This performance was achieved in a time of two minutes.

At cogeneration unit run at 75 and 50 % of nominal performance may be observed a significant power changes. These are caused by a short operation of cogeneration unit, when its performance is stabilized mostly after two hours of operation.

This cogeneration unit is controlled by a heat regime. When is operated only at 100 % of rated power. This type of unit can be operated from 50 to 100 % of the rated electric power. Regulation of electric performance will be performed following way. In the first phase on supply will be mounted current measuring transformer about parameters of 800/5 A, accuracy class 0.5. This output current will be connected to the transmitter simultaneously with the potentials from individual phases. Converter will be convert the calculated electric performance to 4-20 mA. When 4 mA will be correspond to −200 kW and 20 mA−525 kW. The output current loop will be connected to the control machine, which will give impetus of operation of cogeneration unit. A simplified diagram is shown in Fig. 8.

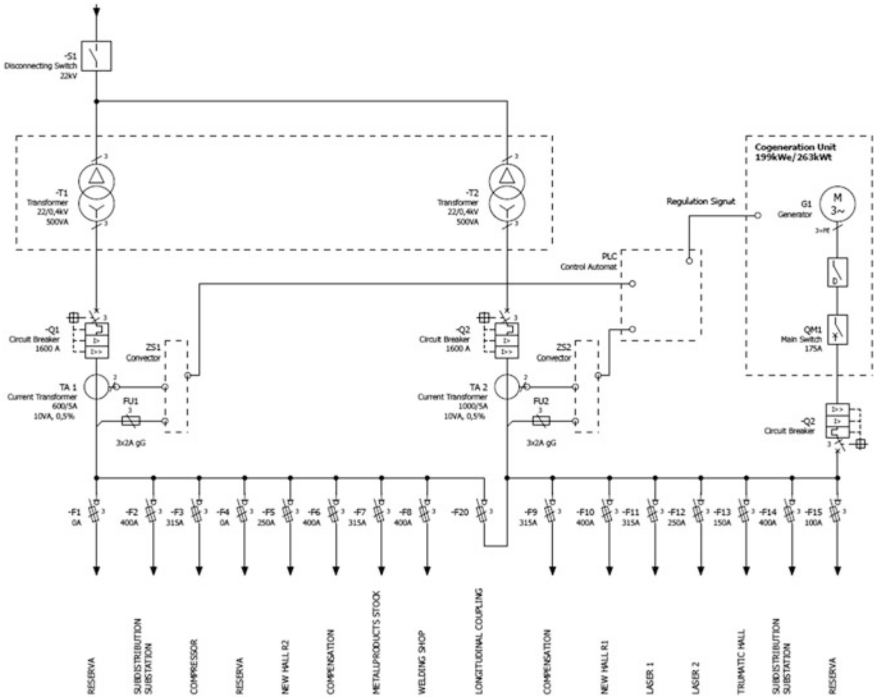

Fig. 8 Simplified wiring diagram of regulation

Further, to the control system will be connected individual information about the operation of cogeneration unit. Among which will include: a power failure, gas leaks, basic failure of cogeneration units. This information will be sent via GSM communication in SMS form to preprogrammed numbers [3, 4].

4 Conclusions

This article aims at verifying regulation of cogeneration unit not only from a theoretical point of view, but also from the practical. At the current regulating of heat and electrical performance by one source always arise problems. The biggest problem arises if we have total discharged an accumulation tank and we can’t run the cogeneration unit because of the overflow of electrical power into the network. This problem is solved by closing the old (original) heating equipment (gas boiler, gas burners). For this reason there was installed accumulation tank which regulates heat consumption. One of the important factors is devise an algorithm that will turn on and then turn off running of the unit. Another factor is also the operation time at which is not recommended turn off the unit under running time of two hours. The aim of resolution is also the option of analysis of regulation regarding to variable loads in the industrial network. It is necessary to devise an algorithm to regulate the running of cogeneration source.

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