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Technical and Economic Aspects and Experience from 6 Years of Operating the Technology Using the Waste Heat from the Exhaust Gases of Heat Sources and 3 Years of Operating a Heating Plant in an Autonomous, Island Regime

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Abstract: This article is focused on technical and economic evaluation of more than 6-years experiences of operating the Waste Heat Recovery technology—the manner and system of flue gas processing generated in the combustion process in heat & power plants, cogeneration units, etc., which burn the gaseous fuel, primarily natural gas, or methane, biogas, geothermal gas, or other gaseous mixtures containing hydrogen. The solution proposes a more effective and non-traditional use of gaseous fuel for heating, the flue gases of which are processed in order to extract additional utilisable heat, with potential elimination of CO_2 from them. Deploying of the heating plant in an island regime (OFF-GRID) enables definition of the benefits brought by the 3 years of operational experience and presents visions for the future offering the possibility to utilise the support energy services at the municipal as well as regional level.

Key words: Natural gas (NG), liquefied natural gas (LNG), liquefied propane gas (LPG), combined heat & power (CHP), renewable energy sources (RES), waste heat recovery (WHR), international gas union (IGU).

1. Backround/Introduction

2015 Journal's edition [1] article was oriented to the principle of the new technology which enables repeated use of flue gas heat generated by burning of gas fuels in heating boilers. The technology is based on the principle of cooling of the flue gases under the dew point level where the water vapours condensate intensively and the condensation heat contained in the flue gases is then released at even higher rate. Therefore, only dried flue gases are released into the atmosphere, cooled to approximately 20 °C, which is not a common heating industry practice. The source of renewable energy (RES) acquired in this way can be then used efficiently together with other RES in the following technological processes. Simultaneously, using an additional technological solution will enable separation of CO_2 from flue gases. As a result, this technological innovation saves energy necessary to heat the heating medium in the recurrent sleeve from 55 to 60 °C.

The new technical solution, also known as WHR (waste heat recovery), was for the first time introduced at the IGU's International Gas Research Conference in 2014 held in Copenhagen which was dedicated to innovative solutions in gas industry. The feedback on the presentation of the WHR technology at this conference led to publishing of articles in professional journals in Germany [2], USA [3] and Russia [4].

2. Problem

(1) Industrial use of efficient waste heat from heat sources is needed.

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(2) Operation of installed high efficient CHP units must be mostly interrupted during the summer period.

(3) To respect actual environmental problems.

(4) To sort out a new way of getting energy from RES.

(5) Actual need to significant optimisation of power fluctuations of power & heat plant's deployed components (CHP units, high-powered heat pumps and absorption coolers).

3. Practical results

Experience acquired particularly during summer enabled correct setting of the number of heat pumps (i.e. 2 heat pumps out of 4). The number of active heat pumps (Fig. 1) at any particular time depended on the achieved coefficient of performance—COP (COP = the proportion of measurable performance of the heat pump and its power input). This represented an important step to optimise the number of deployed heat pumps. Measuring of heat pump efficiency is performed continually—on each of the heat pumps there is a meter installed that measures the flow per hour as well as a meter monitoring entry/exit performance output and power input in kWh/hour (Figs. 3 and 4). Conversely, during the extreme summer heat, it was necessary to deal with the complex issue of emergency cooling of the technology components by mounting of fans (which was accompanied by an increase in power consumption), or by addressing the issue of an efficient cooling compound for the heat pump.

Operation of the boiler room in the transition period, i.e. when the gas boilers need to be operated for heating for less than 24 hours a day, or when operation requires less than 50% of the total heating capacity of the boiler:

(1) Maintain all 4 heat pumps in operation for the full period of 24 hours while using them for the required volume of heat and power generation.

(2) Reduction in the number of CHP units in operation to 2 or 3 units respectively.

4. Conclusions I

After 6 years of successfully operating the WHR technology in our company we can present the following:

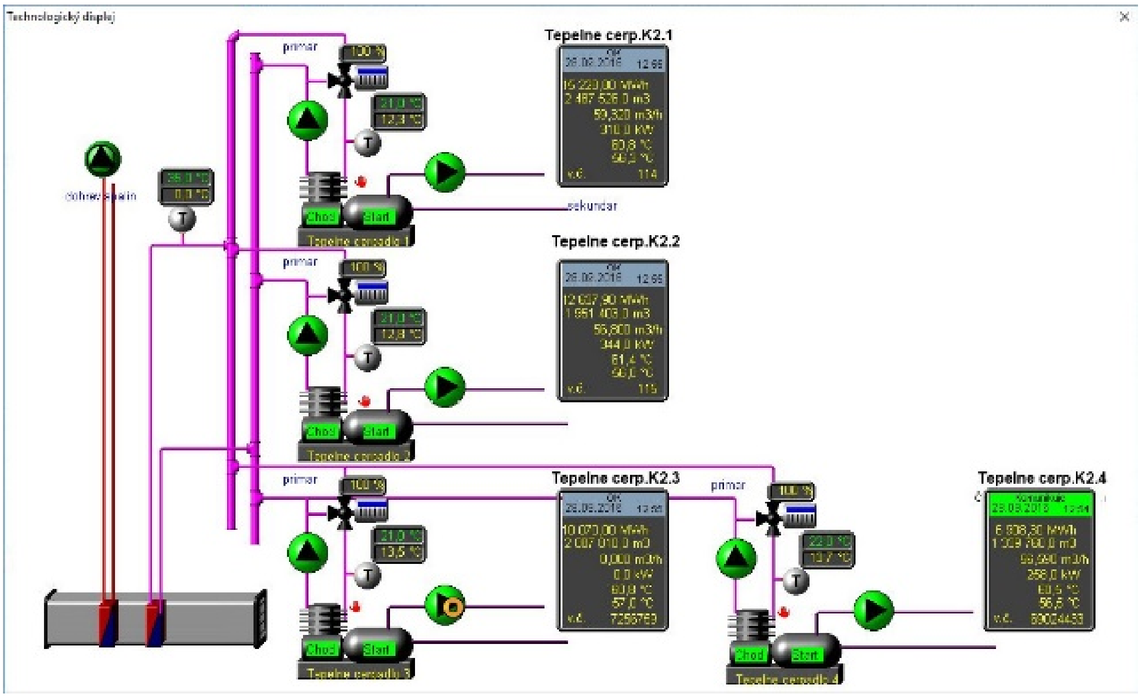

Fig. 1 The heat pump system metering scheme.

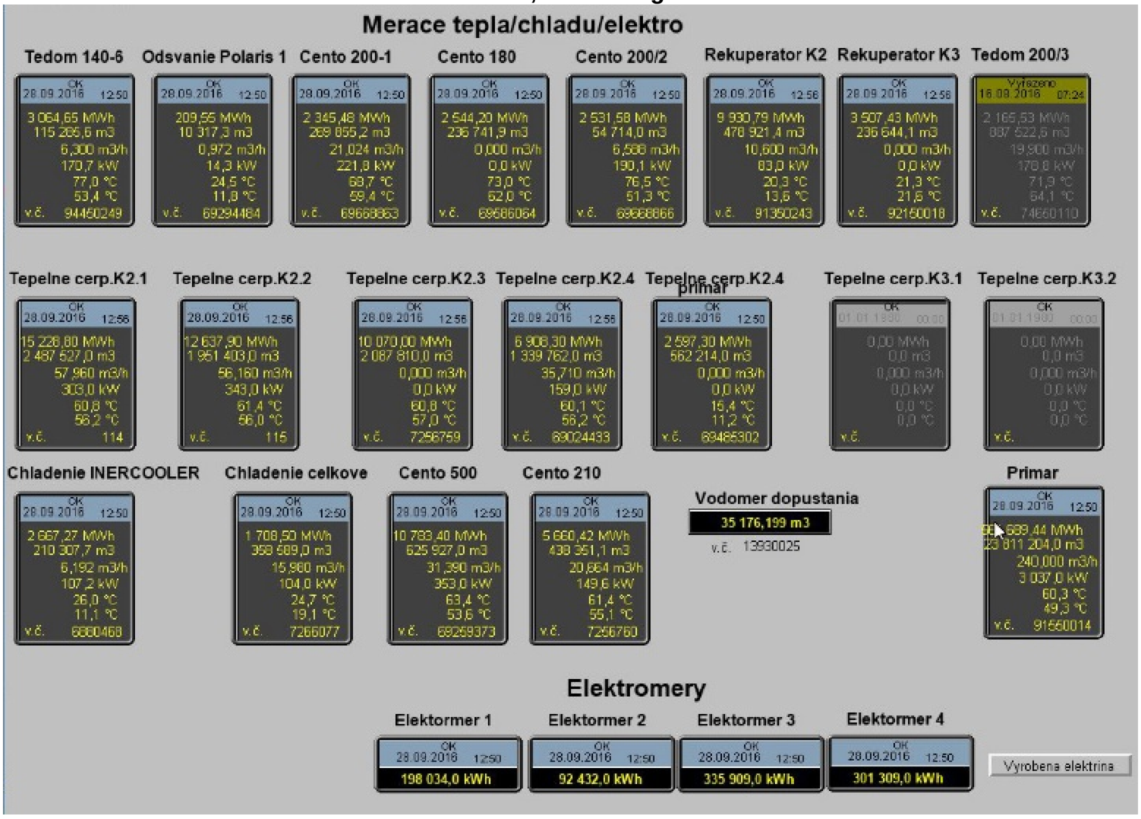

Fig. 2 Monitoring of boiler room technological component.

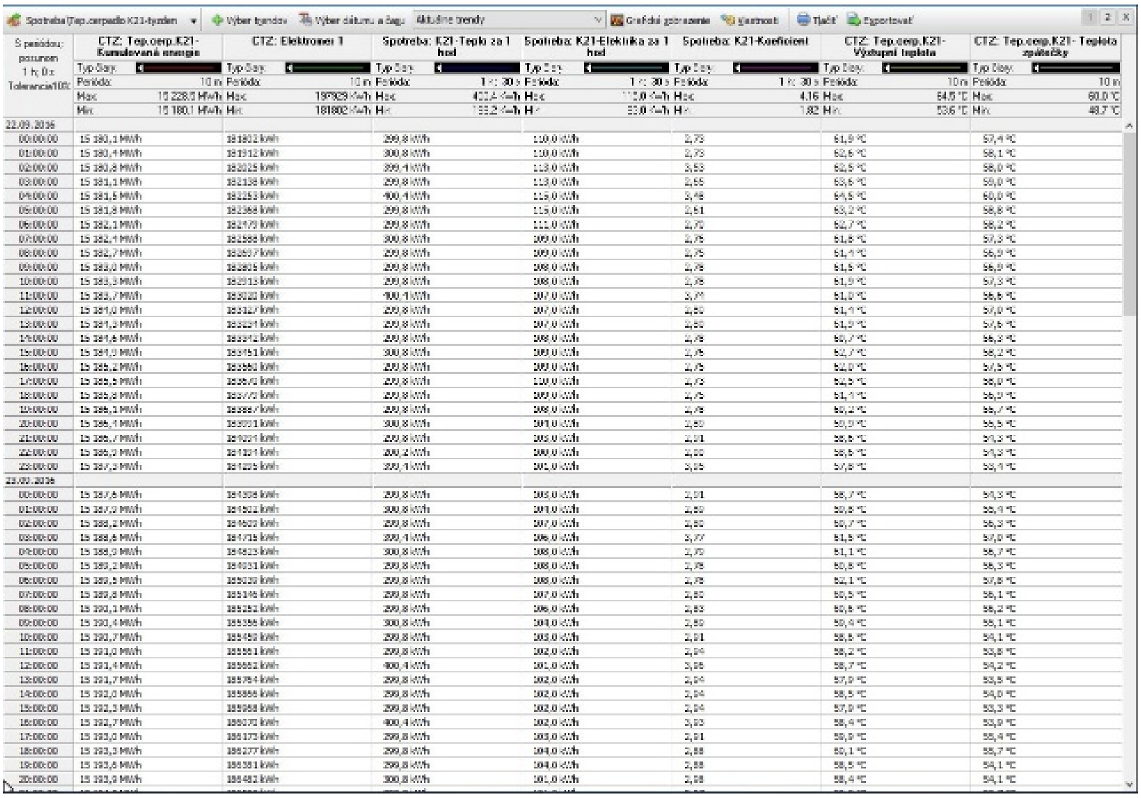

Fig. 3 Overview of the readings from the COP coefficient meter of the heat pump/24 hours.

Spotreba\Tep.cerpadlo K22-mesiac | Výber trendov | Výber dátumu a času | Aktuálne trendy | Grafické zobrazenie | Vlastnosti | Tlačiť

	Spotreba: K22-Teplo za 1 den	Spotreba: K22-Elektrika za 1 den	Spotreba: K24-Koeficient za den
	Typ čiary:	Typ čiary:	Typ čiary:
	Perióda: 1 d	Perióda: 1 d	Perióda: 1 d
	Max: 7 200,2 kWh	Max: 2 490,0 kWh	Max: 3,60
	Min: 0,0 kWh	Min: 0,0 kWh	Min: 0,20
29.08.2016			
00:00:00	0,0 kWh	0,0 kWh	3,60
30.08.2016	0,0 kWh	0,0 kWh	3,43
31.08.2016	0,0 kWh	0,0 kWh	3,53
01.09.2016	5 900,4 kWh	1 846,0 kWh	3,21
02.09.2016	2 700,2 kWh	893,0 kWh	3,56
03.09.2016	0,0 kWh	0,0 kWh	3,37
04.09.2016	0,0 kWh	0,0 kWh	3,52
05.09.2016	1 199,2 kWh	378,0 kWh	3,46
06.09.2016	3 200,2 kWh	1 078,0 kWh	3,05
07.09.2016	0,0 kWh	0,0 kWh	3,07
08.09.2016	799,8 kWh	249,0 kWh	3,33
09.09.2016	300,8 kWh	108,0 kWh	3,48
10.09.2016	699,2 kWh	209,0 kWh	3,41
11.09.2016	800,8 kWh	272,0 kWh	3,54
12.09.2016	3 099,6 kWh	983,0 kWh	2,73
13.09.2016	0,0 kWh	0,0 kWh	3,46
14.09.2016	0,0 kWh	0,0 kWh	3,49
15.09.2016	0,0 kWh	0,0 kWh	3,44
16.09.2016	0,0 kWh	0,0 kWh	3,30
17.09.2016	799,8 kWh	233,0 kWh	2,33
18.09.2016	2 799,8 kWh	865,0 kWh	1,84
19.09.2016	1 900,4 kWh	649,0 kWh	0,85
20.09.2016	799,8 kWh	250,0 kWh	0,22
21.09.2016	**4 299,8 kWh**	**1 435,0 kWh**	**0,37**
22.09.2016	**3 200,2 kWh**	**1 011,0 kWh**	**0,59**
23.09.2016	4 700,2 kWh	1 647,0 kWh	1,65
24.09.2016	3 500,0 kWh	1 176,0 kWh	0,24
25.09.2016	2 700,2 kWh	947,0 kWh	0,44
26.09.2016	4 500,0 kWh	1 642,0 kWh	0,20
27.09.2016	7 200,2 kWh	2 490,0 kWh	0,96
28.09.2016	3 199,2 kWh	1 147,0 kWh	0,21
28.09.2016			

Fig. 4 Overview of the readings from the COP coefficient meter of the heat pump/month.

(1) In a year-round operation, we have acquired a synergic effect: thanks to elimination of water vapours from the flue gas exhausts, the undesired moistening of the chimney was stopped, which had previously been linked to unfavourable impact on maintenance of important boiler room components while the overall utilisation of the set of thermal condensers in the flue gas cooling process has been increased.

(2) Owing to efficient detection of factors related to utilization of RES in combination with gas boilers, overall conditions for boiler room operation have been optimised. The benefits achieved during the summer operation mode of supplying hot sanitary and drinking water and electric power mainly comprised optimisation of the operating conditions by executing saving measures in natural gas consumption, namely the following:

- Seasonal shutdown of gas boilers.
- Reduction in the number of deployed cogeneration units (2 CHP units out of 12).
- Other synergies achieved via utilisation of RES (aero-thermal energy from radiating heat from the uncovered cogeneration units and heat from external environment of the boiler room during extreme weather conditions).
- To objectively calculate the heat generated by heat pump in connection with efficiency of the renewable component of WHR Technology was prepared an independent audit. The audit applied the coefficients in compliance with the conditions following the provisions of the Slovak Regulatory Office. The audit showed 3 heat pumps average heat generation of 6,500 MWh/ year. Technical data of the heating plant is presented in Table 1.

(3) R&D Goals I—Objectives of COM-therm in the sphere of research and development in the area of tri-generation.

In the heating plant operated by COM-therm in the town of Komárno, the new patent-protected technology of tri-generation from solar power was applied in 2018 titled “Autonomous technology of smart tri-generation from solar power”. It is the current objective of our company to present it as an autonomous technology for efficient cooling of buildings using natural gas that is connected to operation of units for absorption cooling. Research into operation of absorption cooling unit to generate cold pointed out to substantial energy reserves of the system; utilisation of these reserves offers an opportunity to replace/reduce the system of heat pumps, which would result in saving of electric power and significant reduction in energy intensity of conventional air-conditioning units.

5. Autonomous Operation of the Power & Heating Plant in Island (Off-Grid) Regime

In 2014, Slovak energy sector underwent changes in the conditions related to conducting of the generated output to the public distribution system which forced COM-therm to deploy the heat plant operation in an island mode, operating in galvanic separation from the public distribution network.

Company's heating plant has become the first heating plant in Slovakia to have installed and tested a functional hybrid autonomous system which is able to optimise the fluctuations in the performance of the CHP unit and high-powered heat pumps while using renewable sources of energy to the maximum possible degree when generating heat/cold and hot water in the island regime operation.

After a 3-year testing operation of the island regime of the heating plant, we can present positive learnings.

5.1 Three-Years of Experience

5.1.1 Stability of Operation

The island regime operation turned out to be stabilised by deploying of the heat pumps and equally safe from the operational perspective as in the case of consumption from the public distribution system. It does not lead to any adverse emergency outages which would be accompanied by any damage to the technological components of the heating plant (Fig. 2).

Safe and smooth performance procedures are implemented when connecting and disconnecting the respective electric outputs. The whole energy system is safely stabilised—the voltage levels in the respective power ranges are stabilised within the authorised and required limits.

5.1.2 Safety of Operation

Physical decoupling from the public distribution system in a galvanically separated regime is ensured and reconnecting the island into the system is not possible without the dispatcher's authorisation. Energy system on the island operates safely and independently from external influences to fulfil the needs of the internal energy system of the power source operator.

5.1.3 Optimisation

Power fluctuations of the deployed cogeneration units, heat pumps and absorption cooler are significantly optimised.

5.1.4 Cost Saving

Operation with a steady power balance led to synergic reduction in the boiler plant costs and to considerable energy and financial savings in consumption of power and natural gas.

5.2 Utilising the Flexible Characteristics of Natural Gas

(1) Natural gas is the regulator of the green component under market conditions, as the system incorporates also renewable sources of power – e.g. solar units and heat pumps. The system provides an efficient and safe possibility to regulate the independent regime of the heating plant without the need for emission allowances and limits. Regulation of the power system leads to increasing or reducing of the required level of power generation for its utilisation which improves the efficiency of the operation and contributes to efficient increase in exploitation of the fuel base.

(2) Natural gas has become an equally valuable source in power generation; even in case of potential outage of natural gas supply, an alternative supply of voltage is enabled from the back-up batteries which are in stand-by mode as they are being continually charged, or alternatively from LNG or LPG sources.

Table 1 Heating plant parameters.

Heating plant parameters	
Heat generation and distribution	300,000. GJ/year
Power generation for internal needs as well as for the public distribution system	10 000 MWh/year
Heat distribution piping (heat accumulation potential)	30 km of heat distribution pipes

(3) Natural gas is a suitable alternating source of energy in case of power outages as it enables generation of sufficient back-up resources. It can replace installations of diesel aggregates in the conditions where non-stop operation is required. Immediate and safe supply of power is a great advantage as the time of power supply is extremely short in case the main supply of power goes out.

5.3 R&D Goals II—Objectives of COM-therm in the Sphere of Research and Development

In the sphere of OFF-GRID deployment of the heating plant in the island regime, COM-therm focused its vision of exploiting the presented benefits not only for the company's heating plant but also to achieve a synergic favourable impact on utilisation capacity of flexible properties provided by natural gas and the protection of the environment at the municipal as well as regional level. Under efficiently regulated energy system using flexible heat sources based on natural gas and renewables, the comprehensive activity offers conditions and the possibility for their inclusion in the category of energy support services.

5.4 Conclusions II

Energy support services utilising flexible properties of natural gas provide good prospects as instruments enabling addressing of unpredictable demands by power customers as it delivers a safe, steady and stable balancing of power states in power systems with connected renewable sources of energy. The full complex of activities under island regime may be—under certain specific conditions—coupled with the public distribution system and deliver some limited range of services for the local and regional energy system, or alternatively for a specific power trader on a contractual base. The vision of creating regional dispatching units and the possibility to provide regulated supply of power for independent power traders at a newly created market with electricity generated from renewables can become a reality in the future.

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