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Transforming Waste Heat into "Renewable Heat"

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Abstract: Introduction: The current worldwide electric power & heat & cool production has a negative impact on the environment by emissions and enormous leaks of low-potential waste heat. Transformation of unused industrial low power heat into "renewable heat" useful to enhance the efficiency of the system is essential and actual innovation in the field of worldwide environmental protection. By introducing and defining the terminology of low-potential, "renewable", "green heat" has created a new, parallel category of research in the energy sector. Traditional co-generation systems produce heat for space heating and hot water and generate electricity. Moving to tri-generation allows growing demand for air conditioning for homes, offices and commercial spaces such as server rooms and switchboards to be met simultaneously or on a seasonal basis. Tri-generation, or combined cooling, heat and power, is the process by which some of the heat produced by a co-generation plant is used to generate chilled water for air conditioning or refrigeration. Usually an absorption chiller is linked to the plant to provide this functionality. The technical solution is related to the new efficient manner and system of simultaneous generation of heat/cold from multiple heat sources, which has not yet been known, but in practice required. New system also enables advantageous utilization of solar power in supporting of the cooling output. The innovative system can be operated also within the existing central heating distribution systems.

Key words: Natural gas (NG), gas boiler (GB), combined heat& power (CHP), combined heat & power & cool (CHPC), co-generation unit (CGU), absorption cooling unit (AU), renewable heat sources (RES), 3-generation technology (3GT), renewable heat (RH), waste heat recovery technology (WHRT).

1. Technology Methodology

The principle of the new technology exploits in the first phase benefits of WHR technology, presented at IGRC 2015 in Copenhagen, Denmark. Technology enables repeated use of flue gas heat generated by burning of natural gas in heating boilers and CHP units [1-5]. The renewable energy source thus obtained is subsequently together with other sources of RES that can be effectively used in the next technological process. Achieved higher degree of flue gases cooling is accompanied with high level of water vapour condensation with release of condensation heat that makes for central heating & power plants optimal physical conditions for essential reduction of generated NO_x emission volumes and for efficient installation of CO_2 separation technologies [1-5].

In the second phase, the technology R&D has also focused on the efficient use of heat energy from other low-potential heat sources generated by the power production and cold also from Ref. [6-8]:

- waste, condensation heat from flue gas of heat sources,
- the aerothermal energy of the decoupled components,
- the thermal potential from the hot circulating, cooling water circuits of AU,
- the secondary generated heat of AU.

Thermal energy of "renewable heat" is obtained by transferring low-potential heat, where the technological equipment transforms the energy into a higher temperature potential usable to support the useful heat output of the system [9].

2. Current Deployment of 3-Generation Operation

Generally, tri-generation systems are known which not only generate heat but also cold, usually by using an absorption chiller or the systems with standard

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compressor cooling that leads to energy losses.

Absorption cooling has three circuits that mutually exchange heat; the circuit of hot circulating water can be connected to the cogeneration unit or another source of heat. The second circuit is the cooling water circuit that removes the heat released by internal exchange. Cooling is most often performed in cooling towers, by this, and basically only results in heat loss. The third circuit is the cold-water circuit, which delivers cooling output to the consumer.

Cogeneration units usually work with temperature gradient of hot circulating water at 90/70 °C where the absorption chiller therefore delivers lower output. The circuit of hot circulating water must be therefore re-heated to at least 100 °C which results in inefficient energy consumption. The power of the cooling units is distributed between absorption and compressor cooling which, however, increases investment costs as well as spatial requirements for location of the system as a whole [7].

3. The Principle of the Technical Solution

The above shortcomings are, to a great degree, eliminated by a new method of cooling where the circuit of hot circulating water of this absorption chiller is connected to the heat source. The cooling water circuit that carries off the heat from the absorption chiller is connected to the entry of the heat pump and the heat pump exit is connected to the recurrent sleeve of heat distribution system.

The cooling water on the exit of 30 °C is lower than the standard temperature of the recurrent sleeve of the central heating system. By transferring the low-potential heat from the cooling water, we acquire extra heat that would be otherwise wasted with no purpose. Also, we manage to stabilize the activity of the absorption chiller by providing for a permanent temperature optimized gradient in the cooling water circuit 25/30 °C. Example is shown below.

The new method of cooling can be simultaneously applied also to any number of the heat source (as seen in Fig. 1). Convenient solution is to deploy a heat container in the circuit of the hot circulating water, e.g. a storage tank that stabilizes the temperature conditions during various fluctuations in the system. We can direct the heat generated from other sources here as well—thermal solar panels or heat transformed from electric power generated by photovoltaic panels can both be transmitted to the storage tank. Photovoltaic panels can also generate power into the distribution system in concurrence with the cogeneration unit.

The implementation of the new system is variable. In the tropics, stronger cooling output will be required and therefore a cogeneration unit will be deployed with the ability to supply the required power; the heat supply required on the entry of the hot circulating water of the absorption chiller that exceeds the framework of the waste heat from the cogeneration unit, shall be covered by solar panels. In mild climate, the system will typically include also a gas boiler as a heat source. Another scheme of deployment includes a gas boiler as a heat source as well as a cogeneration unit; activation of these heat sources can be controlled based on the actual need for supply of heat and power. [6].

4. Technology Autonomy in the NG Synergy with Renewables

The autonomy of the intelligent tri-generation technology also makes it possible to use for areas with underdeveloped electricity distribution networks, as the photovoltaic cell system converts solar radiation to DC EE in the island and can operate in off-grid mode, galvanically separated from the public grid. Last but not least, the abstract focuses on the effective use of flexible properties of natural gas, which enable synergies of natural gas with renewable energy in areas with access to the gas distribution network [7].

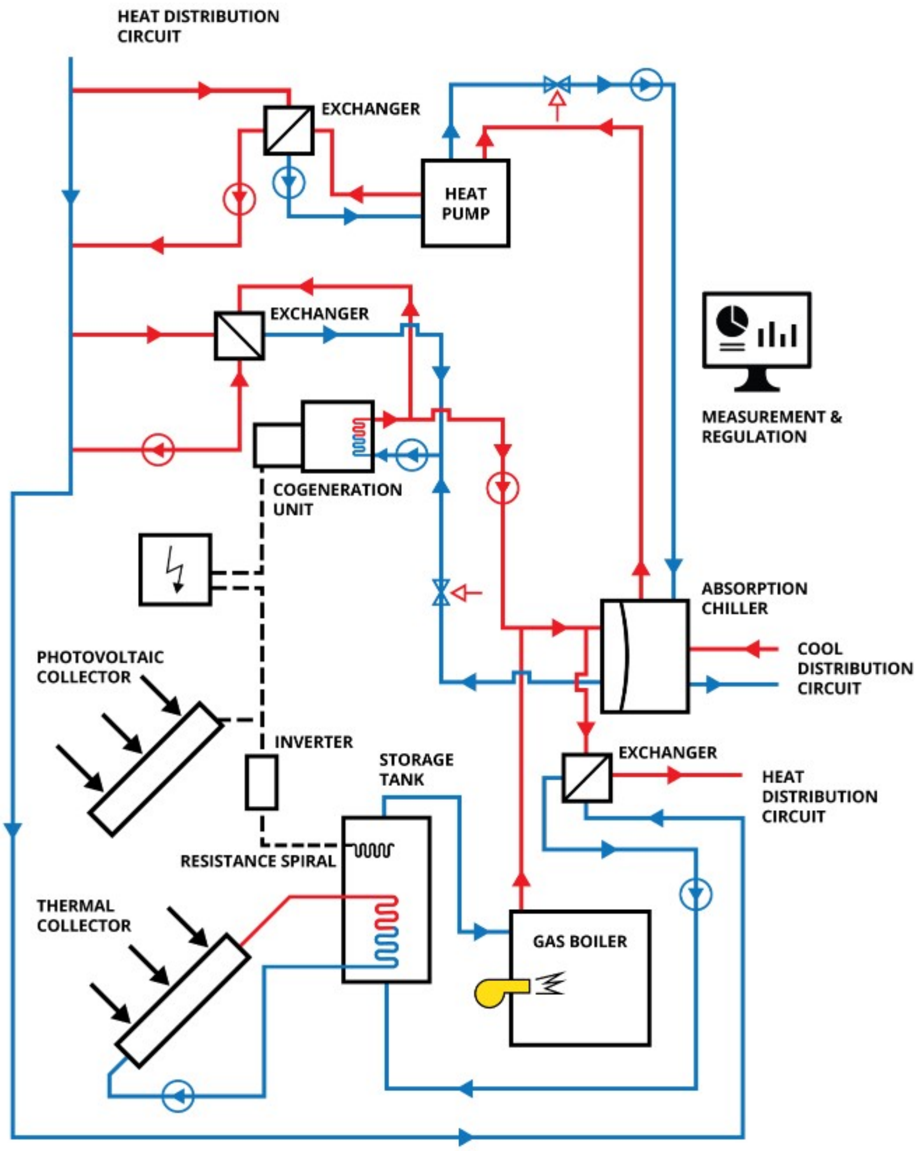

Fig. 1 3-generation boiler room connection scheme.

5. Technology Aims

- to optimize enhanced energy efficiency of year-round operation of the tri-generation method using low-potential waste & "green" thermal energy
- to adopt perfected "renewable" technologies into power stations operation
- to participate in seeking of new environmental solutions by securing more "clean" production of heat and power in centralized power stations

6. Achieved Benefits

The corresponding data can be found in Table 1.

- method enables simultaneous heating/cooling from several heat sources (CHP, GB, solar thermal collectors, photovoltaic panels, accumulation water tank)
- method ensures for AU performance optimization by achieved optimal gradient of 25/30 °C
- stabilization of temperature conditions during various fluctuations in the operation of the entire heating and cooling system
- effective increase in the efficiency of the involved heat pumps
- optimized stabilization of fluctuations of CHP power units and connected boiler room components

Table 1 Plant in 2019 achieved operation specifications.

Total heat network length	30 km (for 30,000 residents, 10,000 apartments, schools, hospitals, administrative buildings)
Total power production	10,000 MW·h/year
Total heat production	51,156 MW·h/year
Renewable heat production/COP (generated by heat pumps section)	10,767 MW·h/year/3.95
Renewable heat production gain	20.9%/3.95
Total cooling production	8,000 MW·h/year

- reduces total gas consumption by at least 20% (i.e. reduces CO_2 emissions production also)
- method eliminates/reduces cooling towers installation
- prepares for central heating & power plants optimal physical conditions for installation of CO_2 separation technologies.

7. Applicability

- Central heating sources (heat treatment plants) the aerothermal energy of the decoupled components
- Waste water treatment plants
- Industry facilities with constant heat/cold consumption
- Wellness, swimming pools, geothermal springs
- Schools, hospitals, hotels, office buildings, institutions, etc.
- The technology is designed for areas with convenient/partially convenient climatic conditions.

8. Conclusion/"Renewable Heat" Definition

The innovative "Intelligent Tri-Generation" technology has the ambition to efficiently use all sources of low-potential heat generated by power, heat and cold production, which have so far been considered unusable under industrial conditions and vented to the atmosphere by tower coolers. By introducing and defining the terminology of low-potential, "renewable", "green heat" has created a new, parallel category of research in the energy sector alongside RES research to address global environmental protection and climate change issues.

"Renewable heat" means low-potential thermal energy, obtained as a by-product from several energy sources where the technological equipment transforms energy into a higher temperature potential, usable to support the useful heat output of the system:

- the energy sector; from industrial processes of other industries, e.g. from the circulation circuits of the hot circulating/cooling water of the absorption refrigeration machine, possibly also from the waste, condensation heat from the flue gases of heat sources of EE production, heat and cold;
- from the secondary circuit of the absorption cooler machine in cold production;
- from the aerothermal energy of the surrounding outdoor resp. internal air created by the operation of various technological processes.

"Renewable heat" contained in the air in the vicinity of energy sources or other energy sources has so far been considered unusable under industrial conditions and has therefore been inefficiently escaped in various forms into the air with negative consequences for the accelerated process of global warming of the environment of cities, municipalities and region. If this low-potential energy is not used, unnecessary additional costs for its removal in the energy and industry production processes arise.

"Renewable heat" is the product of a technological process whose low-potential thermal energy can be classified as a renewable energy source, since its use increases the overall energy efficiency of the energy source concerned [8].

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