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MODERN CHP TECHNOLOGIES FOR DOMESTIC APPLICATIONS FOR COOPERATION WITH RENEWABLE ENERGY

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Small-scale cogeneration is part of the distributed energy resource (DER) strategy, which promotes parallel and stand-alone electric generation units located close to the end user.Generation of electricity on a small domestic scale together with production of heat can be obtained through employing gas engine units, micro gas turbines, fuel cells with efficient electrolysis, Stirling engines or the ORC systems.

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Introduction:

In recent years there is observed a clear tendency, both worldwide and in the countries of European Union (EU), to increase the importance of so called dispersed cogeneration, based on local energy sources and technologies utilizing both fossil fuels and renewable energy resources. Cogeneration, also known as combined heat and power (CHP), is an efficient, clean and reliable approach to the simultaneous production and utilization of electricity and heat from a single fuel source. The principle of cogeneration is based on the recognition that conventional power generation, at its best, is ~ 40% efficient with up to 60% of the energy being lost as waste heat. By harnessing the waste heat from electricity production into useful means can result in higher system efficiencies for fuel utilization of up to 85% or more.

Small-scale cogeneration is part of the distributed energy resource (DER) strategy, which promotes parallel and stand-alone electric generation units located within the electrical distribution system close to the end user. More specifically, DER refers to the decentralized generation of electric power in small- to medium-sized facilities near sites of power demand, in contrast to large centralized electrical generating plants. This has the advantage of minimizing transmission and distribution losses when connected to a centralized grid and promotes increased reliability of supply to the end user in the event of power outages and supply discontinuities. Small-scale cogeneration systems can be operated in two different modes, namely either electricity-driven or heat-driven ones. In the first case, the unit is designed to comply with the electricity demand and the heat is used to contribute to water and central heating purposes. In this case, a supplemental peak boiler may be required to meet total heat demand. In the second case, the cogeneration unit is designed to meet the heat demand while electricity is either used internally or sold to a public grid.

Generation of electricity on a small domestic scale together with production of heat can be obtained through employing gas engine units, micro gas turbines, fuel cells with efficient electrolysis, Stirling engines or the ORC systems. Micro combined heat and power units (CHP) based on organic Rankine cycle (ORC) fit very well to that strategy and in recent years that technology has become a field of intense research. Unlike in the steam power cycle, where vapour of water is the working fluid, ORC use refrigerants, hydrocarbons, solvents or other organic substances. A prototype of such a novel installation of domestic gas boiler fitted with the ORC module has been developed by authors. In the light of the mentioned above DER strategy for production of electricity the research into efficient production of electricity from low grade energy sources is important, as at the moment the available efficiencies resulting from conventional technologies of production are not satisfactory. Resources including geothermal, solar thermal and low-enthalpy heat fall into the category of not very perspective heat sources for the purposes of power generation. However, it can successfully supplement the heat addition to the thermodynamical cycle. Amongst the available options the idea of the organic Rankine cycle (ORC), power generating system using binary mixture as a working fluid or the tri-lateral cycles have attracted some attention. ORC technology has proven to be economical and reliable for using thermal sources as low as 80°C. In addition, there is a great potential for reducing energy consumption by recovering low-grade waste heat that would be otherwise rejected to the surroundings. It has been estimated that industrial low-grade waste heat accounts for more than 50 percent of heat generated.

Implementation of ORC proven to be amongst the attractive methods to achieve relatively high efficiency in converting the low-grade thermal energy to more useful forms of energy. One of the drawbacks in the application of ORC is the temperature matching to the heat source. A good temperature matching is important in minimizing the irreversibilities caused by heat transfer across the finite temperature difference. The ways of minimising that effect have been comprehensively addressed in. When using the ORC to produce electricity from a finite capacity heat source, the temperature mismatching often is inevitable because the source stream is single-phase and possesses a near linear temperature profile along the heat exchanger. That mismatching causes the pinch point to develop, destroys potential work or exergy, and reduces the effectiveness of heat exchangers. To minimize temperature mismatching, a number of possible solutions has been postulated, which are regarded as possible alternatives for utilization of low grade heat source. These can be summarized as follows: use of zeotropic mixtures as working fluid, transferring heat to the cycle at pressures above the critical pressure, or finally the incorporation of Organic Flash Cycle (OFC) Additional option exists if trilateral flash cycle is used. Generalising, the new approaches to improving the energy conversion of low grade fluids include utilizing unconventional working fluids and innovative cycle configurations and designs.

The reference technology for converting waste heat to electricity is the subcritical single component ORC (SCORC), also sometimes regarded as the basic ORC.

Zeotropic mixtures exhibit a unique characteristic known as a “temperature glide,” which results in a variation in temperature during isobaric phase change. Adequate selection of working fluid permits a better temperature match to the finite thermal source by avoiding isothermal phase change. Zeotropic working fluid’s temperature glide is justifying the fact that the temperature profile of the thermal reservoir more closely follows that of the heat source. This reduces the irreversibilities in the heat addition process. Additionally, it can potentially improve the net power output and utilization efficiency.

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