Politechnika Śląska w Gliwicach

Wydział Inżynierii Środowiska i Energetyki

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ROZPRAWA DOKTORSKA

Analiza energetyczna układu kogeneracyjnego z silnikiem ZI w zakresie zmiennych parametrów regulacyjnych

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SUMMARY OF DOCTORAL THESIS

"Energy analysis of a cogeneration system with a SI engine in the range of variable control parameters".

The doctoral dissertation deals with problems related to the development of high-efficiency microcogeneration (mCHP) technology by investigating the influence of the control strategy of a reciprocating internal combustion engine on the achieved energy efficiency.

The aim of the dissertation was to investigate the possibility of improving the energy efficiency of a cogeneration system with a spark-ignition internal combustion engine, particularly in the area of partial load operation (electrical power demand). The focus was on developing a method to improve the energy efficiency of the engine without interfering with its design and combustion system and its implementation into a prototype solution. The focus was on organising the load control method for the SI engine in such a way as to influence typical control parameters such as ignition timing, composition of the fuel-air mixture and absolute pressure in the intake manifold in order to achieve the highest possible energy efficiency. A high energy efficiency value means a reduced value of CO2 emissions given the use of hydrocarbon fuels. Ultimately, the optimisation of control parameters should lead to a compromise between the efficiency achieved by the engine and the emission of toxic substances such as carbon monoxide, hydrocarbons and nitrogen oxides.

The work is theoretical and experimental in nature. Chapters I to III present the current state of knowledge on the issues addressed in the thesis. In the remainder of the dissertation, an analysis of the concept of a new load control method for the SI engine is carried out. In order to obtain the data necessary to answer the research questions and hypotheses presented in the thesis, identification tests and tests of a prototype mCHP unit under laboratory conditions were carried out. Specialised measurement equipment was used in the tests. The work is summarised with a report on the results obtained and a discussion therof.

Chapter I presents the current legal environment of the European Union energy policy and Poland's energy efficiency policy after 2020. It further discusses Poland's energy market performance in 2021, focusing on areas of interest for the development of combined heat and power in micro-scale systems, i.e. up to 50 kWel. At the end of the first chapter, the aim, scope and thesis statement are presented.

Chapter II was devoted to the issue of part-load operation of the mCHP system in terms of daily electricity demand. The first part of this chapter presents existing load control strategies. A description of quantitative control for the SI motor and qualitative control for the CI motor. Furthermore, different solutions leading to improved energy efficiency of these motors are presented based on literature studies.

Chapter III is one of the central parts of the thesis. In this chapter, an attempt is made to present the new hybrid control strategy through a detailed description of the operating principle and an analysis of selected issues related to the difficulty of combustion of lean mixtures, such as combustion limit, torque pulsations, speed measurement and control of the mixture composition. The first part of the chapter considers the issues theoretically, while the second part presents their exemplification in the form of laboratory identification tests. At the end of this chapter, the results obtained are briefly presented, including theefficiency and emissions. The chapter is summarised with conclusions from the tests carried out.

Chapter IV deals with another key issue, from the point of view of thework, which is the construction of a prototype cogeneration system with a SI engine. In the first part of the fourth chapter, a simplified mathematical model was described, according to which selected energy parameters possible to be achieved by combustion engines available on the market were determined, and one of them was selected for testing. In the following sections, asynchronous and synchronous generators, a low-temperature heat exchanger, a high-temperature heat exchanger and an oil heat exchanger were selected in a similar way. Master controllerand motor controller systems are described, together with their configurations. Finally, the specialised measuring equipment used for the tests is presented.

Chapter V covers the practical application and testing of the developed hybrid SI engine load control method. It presents tests of a prototype microgeneration system. The research was divided into two stages. Stage one analysed the factors affecting the interaction between the combustion engine and the asynchronous generator. The second stage involved testing the system with a synchronous generator and was combined with a durability analysis of the combustion engine. In both stages, the combustion engine was fuelled with two fuels, i.e. a mixture of propane and butane (LPG) and natural gas (NG). As a result of the work carried out, the results were analysed in terms of electrical power, power generation efficiency, combustion temperature and emissions. Results and analysis of metrological measurements of selected internal components of the tested engine are also presented.

Chapter VI includes a summary of this work, the results achieved and possible future research directions. It also includes a preliminary study of an ammonia-fuelled internal combustion engine formulating a future research problem. This chapter also contains the final conclusions, including those leading to the confirmation of the thesis set out in the dissertation.