Control Studies of Organic Rankine Cycles with Different Working Fluids

T. Zarogiannis\textsuperscript{1}, A. Papadopoulos\textsuperscript{1}, P. Seferlis\textsuperscript{2}

\textsuperscript{1}Centre for Research and Technology-Hellas, Greece
\textsuperscript{2}Aristotle University/CPERI.CERTH, Greece

Abstract

In recent years Organic Rankine Cycle (ORC) systems have gained worldwide attention due to their ability of recovering low-grade heat, their low complexity and ease of maintenance. Their increasing popularity is also explained by their capability of using a variety of heat sources, such as solar, geothermal, biomass and engine exhaust gases, just to name the most important. A significant research effort has been invested in order to further improve their efficiency and the use of mixtures instead of pure fluids has been identified as a promising path of attaining significant gains. The reason is the drastic reduction of exergy losses due to the closer distance between the hot source and the evaporating mixture temperature profiles in the evaporator\textsuperscript{1} compared to a system with a pure component as the working medium. However, the achieved efficiency performance is usually calculated under steady-state conditions.

For ORC to be a viable technology, it should operate safely and efficiently under variable operating conditions due to exogenous changes and operating specifications changes. The main source that is responsible for such variations is the quality of the heat source and more specifically the flow rate and the temperature of the inlet hot stream in the evaporator. Such changes influence the conditions of the working medium stream entering the expander, which is a crucial factor for the efficient energy conversion and safe operation. Other sources of variation in ORC are the pump and the expander efficiencies due to load variation, and the heat transfer coefficients in the heat exchangers.

Consequently, investigating the dynamics of ORC systems is an essential part of the design process. The main goal of this work is to provide a systematic evaluation of the impact that the working medium has on the control system performance in an ORC system.

To this end, a detailed dynamic model for an ORC system consisted of a pump, an evaporator, an expander and a condenser is developed. A compartmental model is used in...
the phase change heat exchangers that is able to dynamically track the boundary between single phase (liquid or gas) and two phases (gas and liquid) regions. The compartmental model incorporates the dynamic mass and energy balances accompanied by constitutive equations. The model also involves a number of empirically defined heat transfer coefficients, and expander and pump efficiencies.

For each working medium mixture, the ORC cycle is resized in order to achieve the specified power generation. The control system is then designed so that the system exhibits quick response to disturbances and operating level variation. The impact of the working medium on the transient performance is investigated, by comparing the response of the power output and of the cycle operating limits and efficiency under disturbance influence. The study rank-orders the working mixtures that look most promising in terms of efficiency and transient performance. Dynamic control system performance therefore becomes an additional factor in determining the most suitable working medium for the given ORC system.