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Simulation based performance evaluation of biomass fired cogeneration plant with ORC

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Abstract

This paper presents the concept of software tool for planning of operation of a cogeneration plant and its diagnostics. Functionality of the tool is discussed on example of a newly built biomass fired system, that consists of VAS thermal oil boiler and the Turboden T6−CHP ORC unit of 606 kW electric power output. An initial model of the plant has been built using Ebsilon Professional simulation software. The results of simulations show that state parameters of the system can be modelled with relatively good accuracy. The operation of the plant is simulated assuming different thermal loads, ambient conditions and biomass quality. Sensitivity to operating conditions is examined. General performance indices are presented as well as some possibilities for improvements are identified.

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Keywords: Biomass combustion, ORC, computer simulation,

1. Introduction

One of today's challenges in the energy sector is to ensure the continuity of price competitive and affordable energy supply to consumers under rigorous environmental constraints. This requires rational decisions about the operation of generation assets and networks as well as about repairs and modernizations. Resource efficient, price competitive and low-carbon energy management requires in production plants relevant decision support systems

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(DSS) implemented in the form of software tools with a specific functionality. Key features of such system are optimal control of plant operation and on-line diagnostics.

Nomenclature

DSS	Decision Support System
LHV	Lower heating value [kJ/kg]
m	Mass [kg]
ORC	Organic Rankine Cycle
P	Electrcic power [kW]
Q	Heat [kJ]
T	temperature [°C]

Greek symbols

η	efficiency [-]

Subscripts

bio	biomass
C	condenser
DHS	District Heating System
el	electric
f	forward
i	isentropic
MDM	related to working fluid
nom	nominal
ov	overall

Nowadays the most popular technology for small and medium scale decentralized biomass fired cogeneration plants is the Organic Rankine Cycle (ORC). The number of plants of this type is constantly growing. Although the technology is commercially available and proven in a number of plants, there are still some issues to be considered in the context of performance improvement. In existing cogeneration plants, the main issues are related to the control of the biomass combustion process and to the management of plant's heating load.

New Supervisory Control and Data Acquisition (SCADA) and automation systems have opened possibilities for the development of software tools for supporting decisions in the field of plant operation as well as in modernization projects. Collection of historical data together with on-line measurements available within SCADA allow identification of energy conversion processes and calibration of mathematical models. Functionalities of an effective DSS in the case of biomass fired cogeneration plant are as follows:

- Mathematical model of the existing technological system
- Data acquisition
- Data validation and reconciliation (DVR)
- Verification of measurement equipment
- Performance assessment by verification of measured parameters against model calculations (on-line diagnostics)
- Load predictions
- Performance simulations
- Optimal operation decisions (optimal production programme, Model Predictive Control)
- Optimal future investment decisions (optimal modernization).

Block diagram of a concept of advanced DSS for cogeneration plant is presented in Fig. 1. Such software tools can be especially useful in a case where biomass fired cogeneration plant is operated in parallel mode with other production units such as boilers or gas engines. A basic DSS for a thermal power plant can be built using commercial software such as Ebsilon Profesional, Thermoflex IPSEpro and other similar packages. More advanced tools are plant dedicated and tailored software packages.

The most important element of the presented concept of the DSS is a reliable mathematical model of the technological system. In general the model is used for predictions of behavior of the plant under variable working conditions (control mode) and comparisons of measurements against model calculations (diagnostics mode).

Many works and different approaches to modelling of ORC technology have been presented in the literature. Most of them are oriented on development of an effective plant control strategy. Dickes et. al. [1] created the "ORC modelling Kit" (ORCmKit), an open-source library for Matlab, Python and Engineering Equation Solver software packages. The library is dedicated to the steady-state simulation and analysis of organic Rankine cycles that also includes tools for calibration of empirical and semi-empirical models. Andritsosa et. al. [2] developed models of a