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Application Of The Novel "Emeritus" Air Cooled Condenser In Geothermal ORC

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Abstract

The present work aims to investigate the potential advantages in using a novel wet and dry configuration for heat rejection units in ORC power plants. The reference case is a geothermal power plant that exploits a medium temperature brine and uses a closed loop of cooling water to release the condensation heat. In the calculations, the off-design operation of the whole plant is optimized by a techno-economic point of view with a realistic part-load behaviour for the ORC and the use of experimentally validated correlations for the heat rejection section. The performance attainable with the novel LU-VE Emeritus® unit equipped with a water spray system and adiabatic panels is compared with those achievable with the same unit in dry operation. Final results show a marked increase of revenues with Emeritus® units with respect to a dry unit.

Keywords: ORC, heat rejection, system optimization, condenser

1. Introduction

Geothermal ORC plants are usually designed to exploit medium-low temperature geothermal brines and they can inevitably achieve a limited efficiency. This fact, together with the large scale economies of this sector (that push average size to multimegawatt plants), lead to the necessity of rejecting to the environment a massive thermal power. The most convenient solution is to use cooling water from a river or a lake where is available, but in most of the

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cases the remote location of geothermal resources and the scarcity of superficial water require the use of ambient air for the release of the heat of condensation [1]. In these cases (common for geothermal power plants but also relevant for many waste heat recovery applications) the heat rejection unit represents a critical component, affecting significantly the capital as well as the operating costs of the system because of the large electrical consumption of the fans. Direct air cooled condensers (ACC) can be used in some applications while indirect heat rejection through a closed cooling water loop may be preferable for the following reasons:

- It allows reducing the volume of condenser since a compact shell and tube unit can be used. Working fluid inventory is therefore reduced, leading to the possibility of using flammable fluids that are less expensive and often show higher performance with respect to refrigerant fluids.
- Minimum pressure of the cycle can be below atmospheric pressure, with fewer concerns about air in-leakage, leading to increased freedom in the selection of the working fluid.
- Pressure losses of working fluid at turbine discharge are reduced thanks to the compactness of the unit and the absence of long headers for fluid distribution.
- It is possible to use standard components developed in HVAC (Heating, Ventilation and Air Conditioning) field with a potential reduction of the investment cost.

Both with a direct air cooled condenser and with an indirect cooling water system, the use of a dry heat rejection system involves a marked reduction of annual plant energy production, especially in locations with significant yearly temperature variations. A possibility for limiting the drawbacks of dry cooling systems with much lower water consumptions than cooling tower[†]s is to adopt water spray systems, exploiting the latent heat of water sprayed and evaporated on the fins of the condenser. The LU-VE dry-spray system for ORC plants has been validated in a supercritical R134a ORC demonstration plant [2, 3], as well as in hundreds of applications in HVAC. To further boost this system, the novel LU-VE Emeritus® air cooler introduces adiabatic panels in addition to the spray system and a sophisticated control strategy. The combination of the adiabatic panels and the spray system allows reducing significantly the condensing temperature of the ORC in the hot season for a given cooler footprint. In addition, operation with the sole adiabatic panels active allows keeping low condensing temperature in intermediate seasons without the need of spraying water on the heat exchanger fins.

In this paper the optimal design and the optimal operation of the Emeritus heat rejection section for a geothermal ORC is discussed. Revenues attainable with the selection of the proper operation mode are maximized as function of the ambient temperature taking into account a realistic off-design behavior of both the ORC and the heat rejection unit.

Nomenclature and acronyms

η	efficiency
Δh_{is}	isentropic enthalpy drop in the turbine
s	specific entropy
T	temperature
UA	overall heat transfer coefficient (U) times heat transfer surface (A)
Vr_{is}	isentropic volume ratio at turbine outlet and inlet
HVAC	Heating, Ventilation and Air Conditioning
EC	Electrically Commutated motors

† The yearly water consumption of Emeritus is a small fraction of the one of wet cooling towers (generally between 10-15%, depending on ambient conditions).There are two main reasons for this reduction: (i) water is used only for limited period of time and (ii) a large fraction of heat Is rejected by heating air, rather than by evaporating water.