Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 129 (2017) 615–620

Energy Procedia

www.elsevier.com/locate/procedia

IV International Seminar on ORC Power Systems, ORC2017
13-15 September 2017, Milano, Italy

Cycle and turbine re-optimization on geothermal resources significantly deviating from the expected conditions

Nicolò Lazzarin[a]*, Luca Zanellato[a], Marco Frassinetti[a]

[a]*EXERGY SpA, via Santa Rita 14, Olgiate Olona 21057, Italy*

Abstract

The economic success of a geothermal exploration program lies in finding the right compromise between exploration costs, risk evaluation analysis and execution timespan. It could frequently happen that the preliminary well test results differ from the real long term operating conditions and in addition they usually vary across the years. The purpose of this study is to analyze the effect of changing resources on performances, in several scenarios with different optimal cycle and turbine design. This study will point out that the re-engineering of the first stage of the radial outflow turbine, the so called "nose cone", may recover a big part of the inefficiencies and lead back to a nearly optimal power conversion, with heavily reduced effects on timeframe and costs, compared to other solutions, like the re-design of the whole turbine.

Peer-review under responsibility of the scientific committee of the IV International Seminar on ORC Power Systems.

Keywords: ORC; Geothermal; Nose-cone; Radial Outflow Turbine; CFD; Thermodynamic optimization;

1. Introduction

Between renewable energy, geothermal is the most interesting resource for reliable base-load energy production because geothermal power plants are characterized by very high annual capacity factor and availability. The primary resource consists of a hot fluid coming from an underground reservoir, where a temperature gradient anomaly is combined with the presence of underground water, trapped in a confined area [1]. While attempting to exploit geothermal energy, the key point is the definition of the characteristics of the geothermal fluid contained in the

* Corresponding author. Tel.: +39-0331-1817505; fax: +39-0331-1817731.
E-mail address: n.lazzarin@exergy.it

1876-6102
Peer-review under responsibility of the scientific committee of the IV International Seminar on ORC Power Systems.
10.1016/j.egypro.2017.09.219

basin. Such definition is the leading factor for the design of a geothermal power plant, and its importance and proper characterization become evident while operating the plant [2]. The most important parameter for the classification of the resource is its enthalpy, which is a function of temperature, pressure and vapor fraction. Combining this information with other main factors such as chemical proprieties, composition and well production curve, it is possible to determine the potential resource base in terms of thermal power. Estimated potential resource base can vary from the real thermal power available. This discrepancy causes the so called geothermal resource risk and is due to lack of well data or changing of resource condition during operation. Quantification of geothermal resource risk is always important in the financing of geothermal projects. Sanyal and Morrow [3] conducted a sensitivity study of the internal rate of return (IRR) of a typical geothermal project, and illustrated that the most sensitive variables are resource parameters. Having different operating conditions respect of what assumed during the design of the plant, can lead to a very inefficient solution, with lower electrical net power output. The aim of this study is to analyze the effect of changing resources on performances with different optimal cycle and turbine design. We will point out that the re-engineering of the first stage of the radial outflow turbine may recover a big part of the inefficiencies and lead back to a nearly optimal power conversion, with heavily reduced effects on timeframe and costs, compared to other.

Nomenclature

ACC	Air Cooled Condenser
I_t	Investment on period t
PBT	Pay Back Time
Q	Heat exchanged [kW]
S	Heat exchange surface $[m^2]$
ΔT_{ml}	Logarithmic mean temperature difference [K]
U	Overall heat transfer coefficient $[kW/(m^2K)]$
VFD	Variable Frequency Drive
WACC	Weighted Average Cost of Capital

2. Impact of source deviations on thermodynamic cycle and solution proposed

In order to decrease execution timespan and financial exposure during exploration phase, it may be necessary to estimate geothermal source enthalpy and well production curves with a reduced amount of data. A geothermal source can also change its characteristics over time, i.e. causing a loss in fluid temperature. In these situations geothermal source operating conditions can be different from expected: main cycle components (hot and cold heat exchangers, turbine and pumps) would work in off design conditions. In this section we illustrate the model for simulating the behaviour of the power plant in off design condition, analyse the different possibilities to recover parts of the inefficiencies caused by source deviations and then discuss the pros and cons of each alternatives.

2.1. Simulating Off Design Conditions

There are two basic families of components that will determine off-design performance in an ORC power plant:

- Rotating equipment: Turbines, Pumps, Fans
- Heat exchangers

For rotating equipment, when the design is correct, there are no major issues during off design situations. The efficiency is optimized at the nominal point, so to maintain high efficiencies, you need to remain in around of this state. The behavior in different working conditions can be extrapolated from the characteristic curves. In addition, VFD operation can be applied to the feed pump and ACC fans, in order to optimize control in every situation.