USE OF BINARY CYCLES FOR GEOTHERMAL HEAT SOURCES FROM DIVERSE GEOLOGICAL SETTINGS

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RESUMEN

El uso del ciclo binario en fuentes de energía geotérmicas provenientes de diversos ambientes geológicos. Este trabajo analiza la posibilidad técnica de generar electricidad a partir de recursos geotérmicos de baja a media temperatura disponibles en diferentes ambientes geológicos. Éstos comprenden depósitos hidrotermales no volcánicos tipo conductivos o convectivos que se encuentran muy bien desarrollados en toda la Argentina. El agua caliente almacenada en la mayoría de ellos puede alcanzar temperaturas de alrededor de 100 ° C hasta 150 ° C, pero esta salmuera caliente no es utilizable para la generación directa de electricidad en las centrales de vapor clásicas. En este trabajo se propone que la energía geotérmica podría ser transferida a un ciclo binario como el Ciclo Rankine Orgánico (ORC), para obtener energía eléctrica. El presente trabajo dará una visión general sobre la tecnología ORC con el enfoque de los procesos supercríticos ORC, y la nueva instalación de prueba Monika, en los sitios geológicos más adecuados de Argentina.

Palabras clave: energía geotérmica, Ciclo Orgánico de Rankine, energía eléctrica, reservorios no volcánicos, moderada entalpía.

ABSTRACT

This paper analyzes the technical feasibility of generating electricity from low to medium temperature geothermal resources available in different geological environments. These environments comprise non-volcanic conductive or convective hydrothermal reservoirs well developed all along Argentina. The warm water stored in most of them can display temperatures of about 100° C up to 150° C, but this hot brine is not usable for the direct generation of electricity in classical steam power plants. However, it is proposed here that this thermal energy could be transferred to a "binary cycle", the Organic Rankine Cycle (ORC), and converted into electrical energy. The present work will give an overview about the ORC technology with the focus to the supercritical ORC processes, and the new test facility Monika in the most suitable geological sites of Argentina.

Keywords: geothermal energy, Organic Rankine Cycle, power generation, non-volcanic hydrothermal reservoirs, moderate enthalpy.

The growing demand for energy and the increasing environmental issues are demanding the utilization of renewable energies. The geothermal energy represents the natural and internal heat of the earth that is stored within the rock and its fluids. Through various thermal processes, this heat is slowly transferred to the surface where it can be accessed to provide for various human needs being the most important the electrical power production. It is considered an important renewable energy because of its large reserves, constant production and small environmental impact compared with other renewable energies.

Heat is storage in diverse geological settings. According to the nature of the geothermal source these environments are associated with volcanic regions and non-volcanic regions with active faults in tectonic areas (convective hydrothermal systems) and sedimentary basins (conductive hydrothermal systems) (Pesce 2005). These geological scenarios hold low to high enthalpy reservoirs that can provide energy for direct uses and power generation.

The non volcanic environments usually comprise low to medium enthalpy reservoirs with temperatures that are less than 150ºC, insufficient to produce electricity. However, they are well developed from the Andean region to the east, associated with deep faults and /or sedimentary basins, most of which with important hydrocarbon resources.

Di Pippo (2008) described four possible energy conversion systems that take the geothermal fluids from the production wells, process them for use produce electricity in a power plant and finally dispose the fluids in an effective and environmentally friendly manner. For high enthalpy reservoirs, single, double or dry steam flash power plants are used but in case of intermediate enthalpy reservoirs a Binary cycle is necessary. It is proposed here to use the Organic Rankine Cycle (ORC) due to its suitability with mid-to-low enthalpy sources that can permit to use multiple geological scenarios including the water obtained as a byproduct during oil extraction in the oilfields.

The classical Rankine cycle is a conventional and proven technology that has been around for many years. This thermodynamic cycle, traditional powered by coal or gas, uses water as a working fluid. In contrast to the classical Rankine cycle the ORC power plants uses a special working fluid with unique properties such as low evaporation temperatures, and therefore they are more suitable for lower heat sources of 100-200°C (Vetter 2011).

The choice of working fluid significantly influences the maximum achievable performance. (Saleh *et al*. 2007), investigated 31 different working fluids with geothermal fluid temperatures of 100-130°C. They concluded that the greatest efficiency could be achieved using subcritical cycles and an internal heat exchanger. Schuster *et al*. (2010) and Vetter (2

013) analyzed supercritical cycles with various working fluids and different heat sources and concluded a possible improvement of the net power output.

However, high pressures are required for the fluid to reach a supercritical state and this creates a higher investment cost for the components needed to withstand such conditions.

In order to study the optimization possibilities of ORC processes, the test facility MoNiKa (Modular low-temperature cycle Karlsruhe) is being built at the KIT. It is designed as a small and compact power plant with a thermal power of 1000 kW.

Previous investigations showed that supercritical cycles achieved a rise of the net power output up to 44% compared to sub-critical cycles with isopentane, as they enable better adaptation of the temperature profiles in the heat exchanger (Vetter 2014). The planned test system is therefore designed for a supercritical process with propane as working fluid with live steam parameters of 5.5 MPa and 117 °C.

In order to be more flexible in operation the geothermal water is produced in a local heating station, which extends the range of application and suitable components. Furthermore, the instrumentation of Monika allows balancing the energy- and mass flow of the cycle with higher accuracy compared to exiting power plants. The projected data of the power plant suggest an ORC flow rate of 2.9 kg/s, an ORC pressure of 5.52 MPa, a steam temperature of 117ºC, a net power output of 101,5 kW and a cycle pump power usage of 37,57 kW.

The goal is to install with Monika a standalone test facility for low to mid temperature waste heat recovery. There are several hydrothermal convective/conductive targets in Argentina that can be used for ORC power plants. Suggested geothermal reservoirs are the Chaco-paranaense Basin (Río Hondo) and Colorado Basin (Bahía Blanca-Pedro Luro) because of their geothermal gradients, but in both it is necessary to drill wells. Probable the best areas are related with the oil fields because of their existing infrastructures, mature production technologies and rich reservoir data, which will reduce the initial high cost of this technology (Barredo and Stinco, this congress). The plant located in the oilfield will allow covering a significant share of the local energy demand and will help to increase the confidence for using this promising technology in Argentina.

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