Energy capacity of the geothermal resource and its integration in the electrical energy demand of the island of Tenerife (Spain)

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Introduction

One of the weaknesses of the use of renewable energy sources such as wind and solar in terms of its large-scale integration in electrical systems is its low dispatchability. This problem is even more marked in weak electrical systems like those found on islands.

Geothermal energy is a renewable source that includes among its advantages a high degree of dispatchability, the capacity to supply energy in a constant manner without a dependency on climatological conditions. The Canary Archipelago (Spain) comprises 8 islands of volcanic origin with a high potential for the exploitation of geothermal energy. The case study presented in this paper focuses on Tenerife, whose electrical system is isolated, with no connection with the other islands or the continent. The diverse geological, geophysical, and geochemical studies that have been carried out in Tenerife reveal a high degree of probability of the existence in the island of high enthalpy geothermal resources.

In the work developed in the present paper, zones of interest for the exploitation of the geothermal resources on the island are identified, and an evaluation is made of their energy capacity and the installable geothermal power. The aim is to facilitate the integration of this energy source in a scenario of advancement of distributed electrical energy generation and high renewable energy penetration.

Materials and method

A. Identification of areas with high enthalpy geothermal resources

A 3D interpretation on the basis of magnetotelluric models and seismic topographic models was developed for the island of Tenerife. The green-coloured layer is interesting because, in addition to forming part of the igneous core and, hence, being at a high temperature, it is also composed posed of multi-fractured rock systems associated to aquifers and hydrothermal systems, confirming the presence of geothermal resources and facilitating their extraction. Therefore, given the favourable extraction conditions, this green layer was selected for the present study as an area of geothermal resources with high potential for the generation of electrical energy.

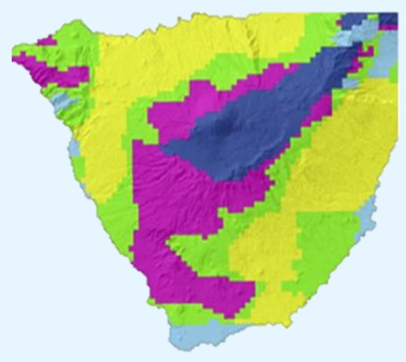

Fig. 1. Joint mesh of electrical resistivity and P-wave velocity at 2000 m b.s.l.

B. Natural protected spaces

Excluded from the calculations are those areas of high geothermal potential situated within the areas of the island designated as Protected Natural Spaces.

Fig. 2. Protected Natural Spaces.

C. Method used to estimate the heat stored in the geothermal reservoir

The volumetric method is one of the most commonly employed techniques to estimate the amount of heat energy stored in a geothermal reservoir (H):

$$H = [(1-\Phi)\cdot\rho_r\cdot c_r + \Phi\cdot\rho_w\cdot c_w](T_i - T_f)\cdot A\cdot t$$

Where Φ is the porosity, ρ_r and ρ_w are the rock and geothermal fluid densities, c_r and c_w are the rock and geothermal fluid thermal capacities, T_f is the abandonment temperature, and T_i, A, and t are the average temperature, surface area, and thickness of the reservoir, respectively.

D. Calculation of the installable electrical power

The installable electrical power is calculated as follows:

$$P = \frac{H\cdot RF\cdot\eta}{t\cdot CF}$$

Where P is the installable electrical power, H is the heat stored in the geothermal reservoir, RF is the recovery factor, η is the conversion efficiency, t is the useful life of the installation, and CF is the capacity factor.

Results and discussion

A. Identification of areas of interest and installable geothermal power

Three areas of interest have been identified for the integration of geothermal plants in the electrical energy generation structure of Tenerife, with an exploitable electrical power of 147.1 MW.

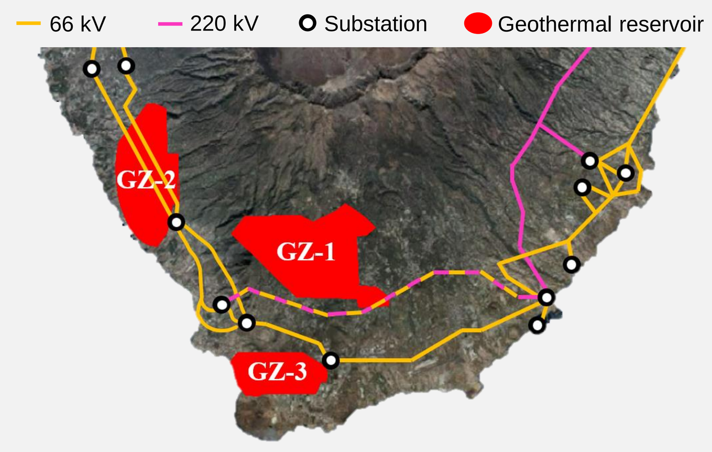

Fig. 3. Plan of the areas of high geothermal potential and high voltage line network.

Zone	Surface area (km^2)	Recoverable heat (TJ)	Electrical power (MW)
GZ-1	40.5	409,092.8	70.2
GZ-2	28.7	290,138.1	49.8
GZ-3	15.6	157,887.9	27.1
Total	84.9	857,118.9	147.1

Table 1. Results for each of three identified areas in Tenerife with high geothermal potential

B. Analysis of renewable contribution increase due to integration of geothermal plants in the electrical system of Tenerife

If an organic Rankine cycle (ORC) geothermal plant complex were to be integrated into the island's current electrical system, the peak renewable contribution on a typical summer day would rise from 45.2% to 75.3%. For the case of a typical winter day, the rise could be from 15.9% to 47.2%.

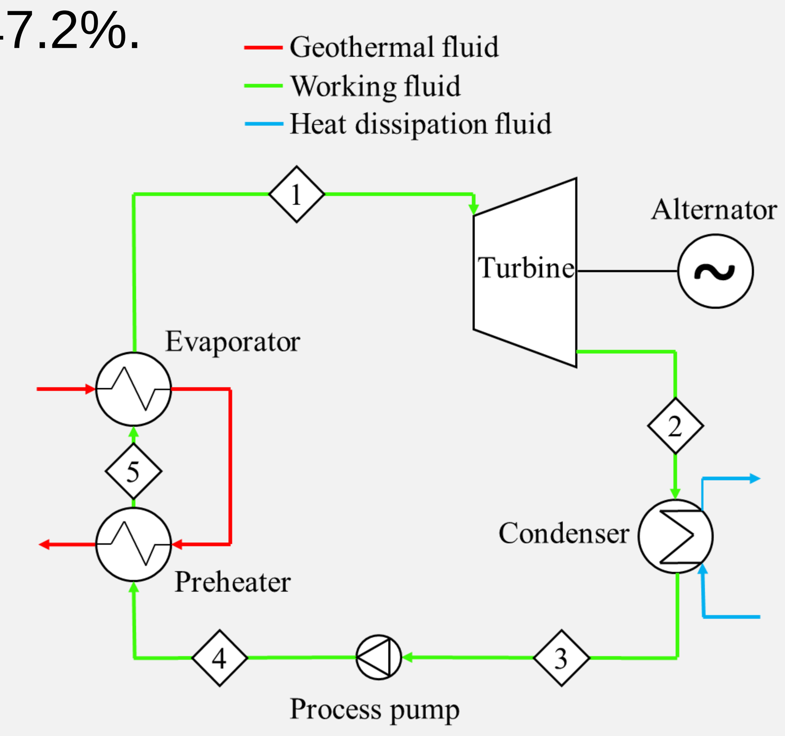

Fig. 4. Layout of an ORC geothermal system.

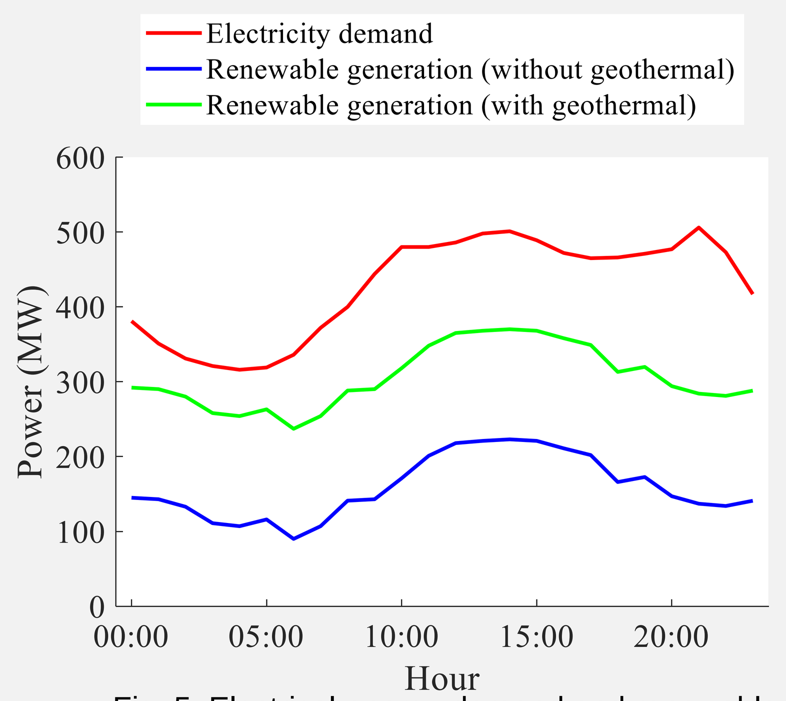

Fig. 5. Electrical energy demand and renewable contribution of a typical summer day in Tenerife.

C. Relationship between geothermal-sourced electrical energy generation and electrical energy demand in seawater and brackish water desalination processes

A desalinated water production of 90.82 hm^3 is expected within the time horizon of 2027. The envisaged annual energy demand for the desalination processes in 2027 would therefore be 299.44 GWh.

This total energy consumption with respect to desalination in 2027 would equate to 27.3% of the electrical energy generated by the ORC geothermal plant complex proposed in this paper.

Conclusions

The island of Tenerife has an important high temperature geothermal potential, which can be exploited for integration in the island's electrical system. Integration of geothermal power in the island's energy plan would entail a significant increase in renewable power and a more distributed generation scenario, with greater dispatchability and an improved electricity supply in terms of safety and reliability.

Before such an integration can be contemplated, however, certain issues would have to be addressed: i) A lack of specific and precise information about the geothermal resource in the three proposed areas, with greater investment required in terms of exploration activities and the application of geophysical and geochemical techniques to know with greater accuracy different characteristics such as the temperature, presence of liquid-vapour and thickness of the geothermal reservoir; and ii) The high economic risk of geothermal installations given the high investment costs. Public financing support would therefore be required in the short-to-medium term.