GEOTHERMOS: a new Matlab code for geothermal potential assessment

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Geothermal energy is a reliable and effective resource for power generation due to its continuous operation, particularly in medium-to-high temperature geothermal systems. We present a new code, called GEOTHERMOS, for assessing the geothermal potential, which is essential for identifying suitable locations and ensuring the profitability of geothermal projects. The new code combines temporal variations in underground conditions with the plant's production metrics. It follows a four-step process: i) subsurface evaluation of temperature and petrophysical parameters distributions, ii) a production borehole model coupled with the geothermal reservoir, iii) thermodynamic simulation of a specific cycle in the power plant, and iv) an economic analysis in terms of the Levelized Cost of Energy (LCOE) and the Net Present Value (NPV) to assess the feasibility of the geothermal power plant. The code flowchart is shown in Fig. 1.

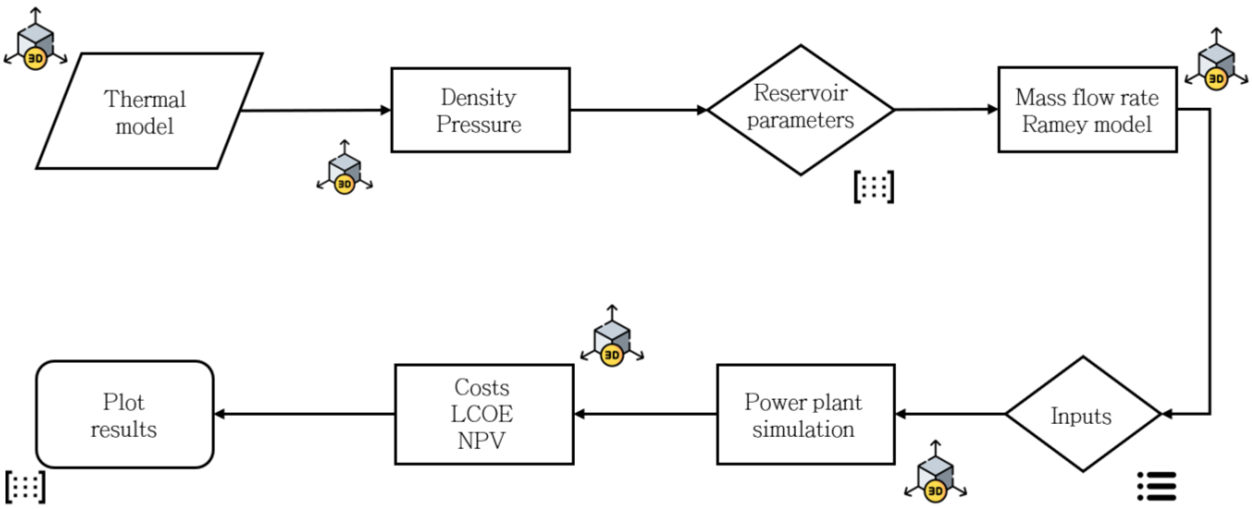

Fig. 1 – GEOTHERMOS code flowchart

Starting with a comprehensive review of available methods and codes, GEOTHERMOS implements the volumetric method, accounting for the vertical and lateral variability of the temperature, static reservoir pressure, and rock permeability distributions. Assuming the absence of severe reservoir heterogeneities, the coupling between the geothermal reservoir and the production well is described analytically by the radial, single-phase, compressible flow model (Muskat & Wyckoff, 1946). To evaluate pressure, temperature, flow rate and fluid phase proportions at the production wellhead, the energy and momentum equations are solved, accounting for heat and head losses along the vertical path. Given the wellhead conditions, the power plant thermodynamic cycle is simulated. Three power plant technologies are considered: dry steam, single flash and binary power plants. To run the thermodynamic cycles, external functions, such as XSteam for water (Magnus, 2024) and Realprop (Volino, 2022) for the organic fluid in the binary cycle, are used to evaluate the required physical properties of the fluids at each stage of the plant cycle. The validation of the implemented thermodynamic cycles is accomplished by comparing the power outputs evaluated by the code with those of real-world geothermal power plants (Zarruk et al. 2014). Fig. 2 shows that the simulated power outputs generally do not exceed the ±10% error bounds, indicating that the simulations are both accurate and precise.

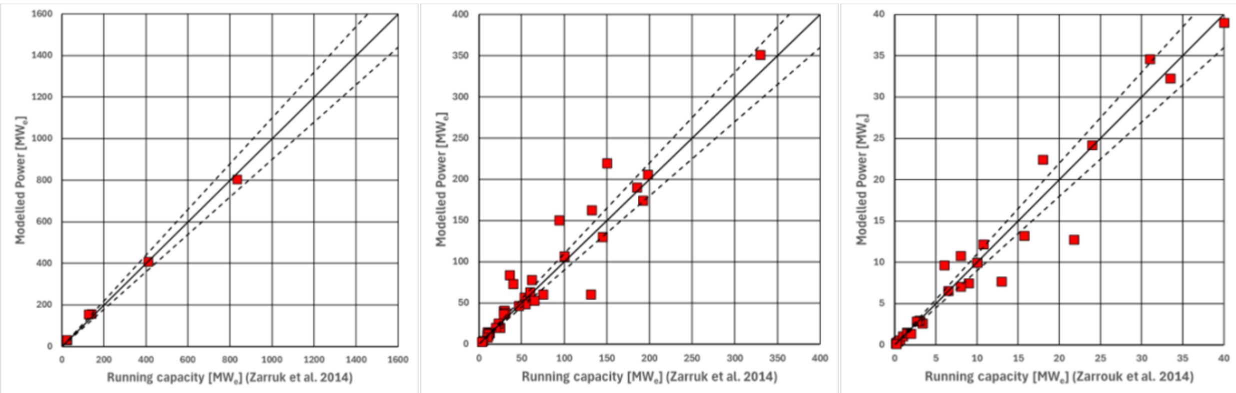

Fig. 2 – Validation of the modelled power plant outputs. From left to right: dry steam, single flash and binary power plant cycles.

The economic model is implemented to assess the feasibility of the plant's operation, based on the evaluation of two parameters: the Levelized Cost of Energy (LCOE) and the Net Present Value (NPV). A 30-year long period is selected as the reference for the techno-economic evaluation. The application of the code to the Cesano-Sabatini area case study confirms its potential for evaluating geothermal resources. Preliminary observations of temperature and pressure at different depths suggested that a dry steam plant would be the most favourable option. In conclusion, further developments of the code will generate a powerful tool for assessing the geothermal potential, aiding in the selection of optimal location for extracting geothermal fluid and reducing uncertainty related to the geothermal power plant projects.

Acknowledgements

InGEO is a PRIN 2022 PNRR Project and has received funding from the European Union, Next Generation EU.

References

Muskat, M. and Wyckoff R.D. (1946). The flow of homogeneous fluids through porous media. McGraw-Hill, 763 pages.

Magnus, H. (2024). XSteam, Thermodynamic properties of water and steam. MATLAB Central File Exchange. Accessed: Sep. 04, 2024.

Volino, R. J. (2022). A MATLAB Based Set of Functions for Finding Thermodynamic Properties and Solving Gas Turbine and Other Thermodynamics Problems. In Volume 5: Education; Electric Power; Fans and Blowers, American Society of Mechanical Engineers, Jun. 2022.

Zarrouk, S. J. and Moon, H. (2014). Efficiency of geothermal power plants: A worldwide review. Geothermics, 51, 142-153.

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