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Towards an open-source digital twin for subsurface geothermal systems: a proof-of-concept study for a doublet system

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Geothermal energy can provide clean and sustainable baseload energy for heating, cooling, and power. The injected working fluid undergoes flow and heat transfer within the surrounding porous rocks during the geothermal reservoir extraction. The geological complexity and lack of data require digital technology like computer simulation to assist in the optimization and decision-making of operation strategies. A digital twin denotes a virtual representation of a physical product, process or facility, and is used to understand and predict the physical counterpart's performance. A digital twin for geothermal production can help to mitigate operational risks, reduce maintenance costs, extend reservoir longevity, and enhance overall sustainability of a geothermal resource.

We propose a workflow for an open-source digital twin for geothermal energy that contains the following elements: a) Well logs and seismic data are utilized to design multiple reservoir models that capture possible geological scenarios using the Rapid Reservoir Modeling (RRM) software. RRM is a sketch-based modelling software that allows users to rapidly sketch geologically consistent models in 3D. b) Possible property distributions will be assigned to geological domains to capture uncertainty in the petrophysical data. c) The Delft Advanced Research Terra Simulator (DARTS) is combined with machine learning techniques to create proxy models that enable fast simulations. d) As new production and monitoring data becomes available, data assimilation techniques like Ensemble Smoother with Multiple Data Assimilation (ESMDA) are applied to update property distributions for each scenario. This iterative process of data assimilation will help users constrain geological and production uncertainties, both of which are key to optimizing operational strategies.

We demonstrate the digital twin framework using a proof-of-concept study of a low-enthalpy geothermal system located in a channelized fluvial reservoir. Heat is produced from a geothermal doublet. The geological scenarios were designed using RRM. These models consider key uncertainties, such as Net to Gross, sinuosity of the channels, paleo flow direction, and the distribution of porosity and permeability within the geological domains. One of the RRM models was chosen to be the "truth case"for which synthetic production data (well temperatures and pressures) and dynamic data along the wells were simulated using DARTS. Each individual RRM model adheres to the well constraints "observed"for the truth model. DARTS was applied to rapidly predict production performance for each scenario, and these data can subsequently serve as the training set to obtain the proxy model. Both machine learning and ESMDA will be performed to reduce the difference between the prediction and observation of truth case to update reservoir properties.

The outcomes of this proof-of-concept study demonstrate the feasibility of the digital twin framework for geothermal systems. A broader range of monitoring data in the reservoir and transient data will be included in the future to enhance the performance of the digital twin in geothermal energy applications.

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