Simulation-Based Evaluation of Effectiveness of Fiber-Optic Sensing in Monitoring Water Circulation in Enhanced Geothermal Systems

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Outline

➢ Major Stimulation Mechanisms in EGS
  • Shear activation or tensile fracturing?

➢ Fiber-Optic Sensing in Geothermal
  • DTS, DAS, DSS
  • Sensitive enough for monitoring purpose?

➢ Numerical Model and Analysis
  • Coupled THM model
  • Synthetic FOS signatures: insightful for monitoring and optimization?

➢ Summary
EGS Stimulation Mechanisms

- **Conventional EGS Design**
  - Vertical or deviated well
  - Shear stimulation of existing fractures

- **Modern (next-generation) EGS Design**
  - Horizontal wells
  - Multistage hydraulic fracturing

- Rely on extensive discrete fracture network
- Percolating network with adequate transmissivity
- No proppant; conductivity by fracture asperity
- Enough connectivity between wells???

- Seem like a viable way to build connectivity
- Technical challenges/high costs
‘Next-Generation’ EGS

Utah FORGE

- Stage 3: perforated
- A narrow planar fracture zone

Fervo Energy

- Two horizontal wells
- 16-stage plug-and-perf hydraulic fracturing
- No technical barriers

McClure (2023)

Norbeck et al. (2023)
Fiber Optic Sensing in Geothermal

- **Distributed Temperature Sensing**
  - Up to hundreds of degree Celsius  

- **Distributed Strain Sensing**
  - slow strain: geomechanical monitoring
  - LF-DAS; RFS-DSS: < $1\mu\varepsilon$

- **Distributed Acoustic Sensing**
  - Rapid strain: seismic monitoring
Numerical Model

- coupled Geomechanics, fluid Flow, and heat Transport Simulation (GeoFTSim)
- P-T diagram of water thermodynamic properties
- Sequential-implicit coupling scheme: stable, flexible, accurate
Validation

- Thermal-poro-mechanical consolidation
Simulation Model Setup

- Simplified conceptual model, following the modern commercial setting
- Injection: perforated; Production: Open-hole

Temperature distribution

Strain-change distribution

Fercho et al. (2023)
Basic DTS/DSS Responses

Production Well 1

Temperature

Production Well 2

Temperature

Strain

Change
Basic DTS/DSS Responses
Flow-Localization Signatures

fracture configuration  temperature distribution  strain change distribution
Flow-Localization Signatures

producing temperature

temperature

strain change
Multiple High-Conductive Fractures

fracture configuration  temperature waterfall  strain change waterfall
Multiple High-Conductive Fractures
Mitigation of Flow Channeling

producing temperature

fluid distribution
Summary

• Temperature reduction and associated strain changes can be sensed by DTS and DSS

• In modern EGS design, flow localization is detrimental for thermal recovery.

• Inaccurate identification of channeling flow may lead to unsuccessful operations

• Combined DTS and DSS can identify the issue in real time

• More complex fracture network; field measurements are needed