Monitoring Steam-Assisted Gravity Drainage (SAGD) with EIT

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Abstract: Steam-assisted gravity drainage (SAGD) is a technique that has been developed to efficiently extract bitumen from deep reservoirs. We propose using electrical impedance tomography (EIT) for real-time monitoring of SAGD wells to maintain optimal operating conditions. Several electrode configurations along the pipelines and measurement strategies are presented and compared.

1 Introduction

In Canada, about 80% of bitumen are located in deep reservoirs where only a small fraction has low enough viscosity to be recovered using conventional crude oil pumping techniques [1]. The steam-assisted gravity drainage (SAGD) method has been developed to successfully recover such bitumen [2]. The SAGD method uses continuous injection of high-pressure steam to reduce the viscosity of the bitumen by increasing its temperature and water content (Figure 1). This low-viscosity bitumen drains (via gravity) to a lower pipe where it is collected and pumped to the surface. Several parameters affect SAGD production rate and longevity: spacing between pipes, steam injection pressure, thickness of bitumen layer, soil types above and below the bitumen layer, physical properties of bitumen, and heterogeneity of all these properties. Good monitoring is essential to maintain optimal SAGD operating conditions [3].

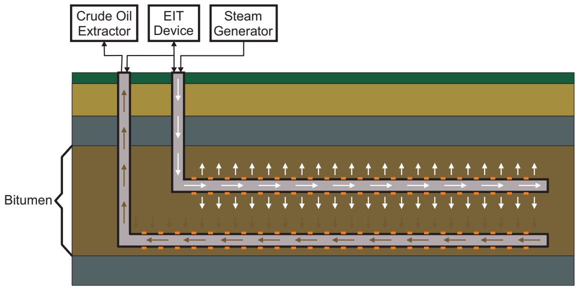

Figure 1: Diagram of steam-assisted gravity drainage. Steam is injected through top pipe while crude oil is recovered through bottom pipe. Proposed EIT sensors are shown as orange rectangles.

To improve SAGD well monitoring, we propose using electrical impedance tomography (EIT) to provide detailed and localized information about the geometry and properties of the soil whose electrical properties are sensitive to composition, water content, temperature, and oil content. Such information would be available in real time as oil is extracted from the reservoir and would be useful to optimize and predict the production rate and longevity of SAGD wells. We propose placing EIT electrodes at regular intervals along both pipelines to image the bitumen reservoir, measure whether conditions are heterogeneous, and how they evolve as oil is extracted and steam is injected. We simulated several electrode configurations and measurement strategies to assess how sensitivity and resolution of EIT images are affected and propose best candidates.

2 Methods

Several 3-D finite element models representing realistic SAGD geometries were built to assess the imaging performance of EIT using five different electrode configurations and three possible measurement and stimulation strategies. The following electrode configurations were considered: 1) ring electrodes uniformly distributed along the pipelines, 2) composite dual ring electrodes where each electrode is subdivided in halves either in the a) vertical or b) horizontal orientations, and 3) composite quad ring electrodes where each electrode is subdivided in quarters either a) orthogonal or b) diagonal to the *x*, *y*, *z* axes.

For each of the above electrode configurations, three measurement strategies were considered: exclusive use of pairs of electrodes parallel (#1) or perpendicular (#2) to the pipelines or a combination of both (#3). Sensitivity images were produced as well as PSF-like images of a moving small target on a horizontal and a vertical axis. For instance, Figure 2 shows four different views of a sensitivity image obtained with quad ring electrodes using a combination of both parallel and perpendicular pairs of electrodes.

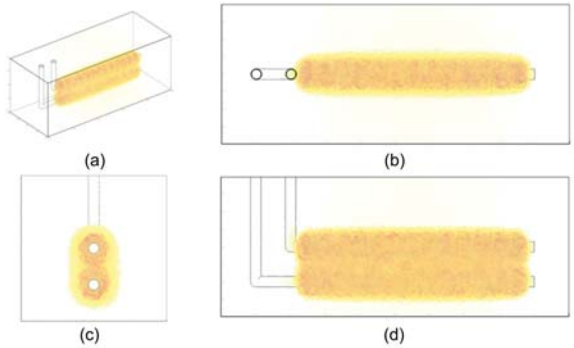

Figure 2: a) 3-D, b) top, c) front, and d) side views of a 3-D image representing areas of maximum sensitivity for a configuration using quad diagonal composite ring electrodes.

3 Discussion

Simpler electrode configurations do not allow distinguishing targets that are located left or right of the pipelines because of the implicit axial symmetry of their geometry. Quad diagonal composite ring electrodes seem to provide the best sensitivity and image resolution among the five tested configurations. Measurement strategies involving pairs of electrodes that are both parallel and perpendicular to the pipelines provide best performance. However, poor signal to noise ratio is to be expected for measurements using pairs of electrodes spanning the gap between the pipes.

References

[1] Rahanama F, Elliott K, Marsh RA, et al. In *Future energy: improved, sustainable and clean options for our planet.* 2008
[2] Chung T, Bae W, Lee J, et al. *Energ Source Part A* **34**:219–226, 2011
[3] Al-Bahlani AM, Babadagli T. *J Pet Sci Eng* **68**:135–150, 2009

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