Well integrity monitoring with electric fields by using hierarchical geo-electric models

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Summary

Failure of wellbore integrity is one of the key concerns in operating oil and gas fields as well as abandoned mature fields that are typically considered for long-term CO_2 storage, and may cause dramatic negative environmental impacts. Here, we present a numerical study on the well integrity monitoring by using electric (E) field measurements. The survey setting includes a steel-cased well whose condition is unknown (i.e., intact or damaged) and a surface profile along where the E field is measured once the casing is energized at the well head (i.e., the top-casing method; Wilt, 2016; MacLennan et al., 2018). The changes in the surface E field can be used to detect and constrain the location of well damage.

Here, we obtain the E field responses of the steel-cased wells from the simulated electrical potentials in the DC limit by utilizing the hierarchical finite element method (*Hi*-FEM; Weiss, 2017). The method allows us to represent the electrical conductivity not only on volume elements but also on lower dimensional elements such as facets (2D) and edges (1D) in the unstructured finite element mesh. Since the well casing is represented by a subset of connected edges within the 3D tetrahedral finite element mesh, the surface E field data can be simulated without the need of extensive mesh refinement and high computational cost. Our results support the findings of the previous studies that well breakage results in an anomalous increase in the amplitude of the surface E field inversely proportional to the length of the path from the wellhead. Moreover, our analysis of surface E field data obtained from an energized, damaged well also shows that regardless of the amount, type, and location of well damage, surface E field measurements can identify the presence of damage and provide a reasonable estimate for the compromised portion of the well. In this study, we present various model scenarios to investigate the feasibility of an automated well integrity monitoring with the surface EM data.

Keywords: DC resistivity, electric fields, well integrity monitoring, finite element modeling

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