Using a 3D thermo-hydro-mechanical coupling numerical model to evaluate the extraction strategies of geothermal fields: A case study of the Chingshui Geothermal Field

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Abstract

Geothermal power generation is a vital component of renewable energy development in Taiwan. The commercially operational Chingshui Geothermal Field, located in Yilan County, represents one of Taiwan's earliest and relatively successful geothermal projects. However, the efficiency of the geothermal power generation depends on the temperature of the hot water produced, which can decrease due to improper water extraction management. Therefore, this study employs a thermo-hydro-mechanical (THM) coupling numerical simulation approach to assess subsurface temperature and pressure variations under current water extraction practices. This study begins by collecting prior geological surveys, research findings, physical properties of geological materials, and data on water extraction volumes and temperatures during power plant operations. Utilizing the multiphysics simulation software COMSOL Multiphysics, a simplified geological model is then constructed. The interactions between heat transfer, fluid flow, and solid deformation within the subsurface are considered, thus creating a THM coupling model. Consequently, this study completed the development and simulation of a THM water extraction model for the simplified Chingshui Geothermal Field model. Parameter sensitivity analysis was conducted to understand the effects of different parameters on the THM coupled system. The results show that permeability, thermal capacity, and pumping rate have higher sensitivity to the simulation results compared to other parameters. Subsequently, various water extraction scenarios will be designed and simulated to observe their effects on productivity. This will provide insights for the management of water extraction at the Chingshui Geothermal Power Plant.

Keywords: Chingshui geothermal field, simplified geological model, thermo-hydro-mechanical coupling numerical simulation, parameter sensitivity analysis.

利用三維熱-水-力耦合數值模式評估地熱案場抽注水管理方案：以清水地熱案場為例

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摘要

地熱發電是台灣再生能源發展中重要的項目之一，其中位於宜蘭縣大同鄉的清水地熱案場為發展最早且相當成功的案例，目前已進入商業運轉階段。然而，地熱發電效益取決於生產的熱水量。其可能因為抽注水的管理不當而降低發電效率，甚至導致地熱井之產能嚴重衰退而沒有經濟效益。因此本研究希望利用熱-水-力耦合(thermo-hydro-mechanical coupling)數值模擬方法，評估現有抽注水操作下的取水與岩體中水溫及水壓變化狀況，並嘗試以現有各井體資料，在不同抽注水情境下進行模擬，評估抽注水管理方案。本研究首先蒐集前人針對清水地熱場址進行之地質調查與相關研究成果，並蒐集熱源、流量以及發電廠運作時採用的抽注水量等資料；以多物理場模擬軟體 COMSOL Multiphysics，建立簡化的三維地質模型，並考慮地層內部熱傳、水流及固體變形之間的交互作用，建立熱-水-力耦合數值模式。研究中藉由軟體平台組建不同熱-水-力模組，透過調整各輸入變量進行模擬與分析，以建立適當的熱-水-力耦合模式，並取得合理的參數設定。本研究完成清水地熱場址簡化模型的熱-水-力抽注水模式建置與模擬工作，並進行參數敏感度分析，瞭解不同參數對熱-水-力耦合系統的影響。結果顯示，熱容量及抽注水井流率對於生產溫度變化，相較其他參數有更高的敏感度；滲透率及抽注水井流率對於生產井周圍水壓變化有更高的敏感度。後續將以此簡化模型為基礎，設計不同的抽注水情境並進行模擬，以觀察不同情境設定對產能之影響，用以提供清水地熱電廠抽注水管理之參考。

關鍵字： 清水地熱案場、簡化地質模型、熱-水-力耦合數值模式、敏感度分析。