Deep Underground Engineering for Water Conservancy and Hydropower: Geological Environment, Surrounding Rock Catastrophic Failure, and Technical Challenges (Postprint)

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Abstract

Venturing into the deep Earth represents a strategic scientific and technological challenge that we must address, and the development of deep Earth resources and space has become a crucial direction for China' s future scientific and technological advancement. As a significant clean energy source in China, hydroelectric power' s underground engineering is progressing toward burial depths exceeding thousands of meters. Subject to extremely complex geological environments, deep engineering under existing technical standard systems faces issues of inappropriate design methods and unclear surrounding rock failure mechanisms. There is an urgent need to elucidate the relationship between geological characteristics and depth in deep-buried hydroelectric underground engineering, thereby resolving the blindness and uncertainty in deep underground hydroelectric engineering construction. This paper systematically reviews the concept of 'deep' in deep underground engineering across different industries, and in conjunction with the characteristics of underground hydraulic structures in hydroelectric projects, defines the burial depth for deep underground hydroelectric and water conservancy engineering from perspectives including deep engineering geological environment characteristics and surrounding rock failure in hydroelectric underground engineering. On this basis, it reviews and prospects key technical challenges requiring breakthroughs in deep underground hydroelectric engineering, including precise exploration and drilling-while-sensing, theoretical innovation in large-scale deep-buried cavern group design, engineering layout and intelligent construction, disaster prevention and active control, and intelligent operation and maintenance with emergency escape, aiming to provide technical support for the design, construction, and operation and maintenance of deep underground hydroelectric engineering and to promote deep energy development.

Full Text

Preamble

Concept and Key Technical Challenges of Deep Underground Hydropower Engineering

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Abstract

Advancing into the deep Earth represents a strategic scientific and technological challenge that must be addressed. The development of deep subsurface resources and space has emerged as a crucial direction for China' s future scientific and technological advancement. As a vital clean energy source in China, hydropower projects are increasingly pushing their underground structures to depths exceeding several kilometers. However, subjected to extremely complex geological environments, deep engineering projects under existing technical standard systems suffer from inappropriate design methodologies and poorly understood rock mass failure mechanisms. There is an urgent need to clarify the geological characteristics of deep-buried hydropower underground projects and their relationship with depth, thereby overcoming the blindness and uncertainty in deep underground hydropower construction.

This paper systematically reviews the concept of "deep" in underground engineering across different industries and, combined with the characteristics of underground hydraulic structures in hydropower projects, defines the depth threshold for deep underground water conservancy and hydropower engineering from the perspectives of deep engineering geological environment characteristics and rock mass failure in hydropower underground projects. On this basis, the paper identifies and prospects key technical challenges requiring breakthroughs in deep underground hydropower engineering, including precise exploration and drilling-while-sensing technologies, innovative design theories for large-scale deep-buried cavern groups, engineering layout and intelligent construction, disaster prevention and active control, and smart operation-maintenance systems with emergency evacuation capabilities. The aim is to provide technical support for the design, construction, and operation of deep underground hydropower projects, thereby promoting the development of deep energy resources.

Keywords: water conservancy and hydropower engineering; deep engineering geology; geological environment; rock mass failure; technical challenges

Note: Figure translations are in progress. See original paper for figures.