Research and Application of BIM Technology in the Design of Souapiti Hydropower Station (Postprint)

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Abstract

In hydropower station engineering design, the 3DEXPERIENCE platform from French company Dassault Systèmes was introduced for the first time to implement forward collaborative design. By integrating a series of BIM application points throughout the entire design process and based on ENOVIA, design deliverables were uniformly integrated on the 3DE platform, ensuring the optimality and safety of design outcomes, improving product quality, and forming continuous deliverable digital engineering assets. Combined with secondary development of Composer, an independently developed design information management system was established to perform lightweight processing of BIM models, facilitating the management of site design documents associated with BIM models at the construction site, and enhancing the information management level of hydropower station projects.

Full Text

Preamble

Research and Application of BIM Technology in the Design of Suapiti Hydropower Station

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Abstract

This project marks the first introduction of Dassault Systèmes' 3DEXPERIENCE platform for forward collaborative design in hydropower station engineering. From feasibility study through preliminary design to construction drawing stages, the BIM model was progressively refined. By integrating a comprehensive series of BIM applications throughout the design process and utilizing ENOVIA to unify design deliverables on the 3DE platform, the project ensured optimization and security of both the design process and its outcomes, improved design quality, and created continuous, deliverable digital engineering assets. Through secondary development of Composer, we independently developed a design information management system that performs lightweight processing of BIM models, facilitating the management of site design documents associated with BIM models at the construction site and enhancing project information management capabilities for hydropower engineering.

Keywords: 3DEXPERIENCE; collaborative design; forward design; hydropower station

1.1 Project Overview

The Suapiti Hydropower Station (geographic coordinates: 10°25’ N, 13°15’ W) is located on the middle reaches of the Konkouré River in western Guinea, 135 km from the capital Conakry. The reservoir has a total storage capacity of 7.489 billion m^3, installed capacity of 450 MW, and annual power generation of 2 billion kWh. Classified as a Grade I project with large (Type 1) scale, the dam is a roller-compacted concrete gravity dam with a maximum height of 120 m. Upon completion, the project will reverse Guinea’ s domestic energy shortage and transform the country from a power importer to a power exporter. Project renderings are shown in Figure 1 [Figure 1: see original paper], the BIM model in Figure 2 [Figure 2: see original paper], and construction status in Figure 3 [Figure 3: see original paper].

1.2 Engineering Challenges

As an international project, this engineering endeavor faces four primary challenges [1]:

First, extremely tight schedule and heavy workload. The F+EPC (Finance, Engineering, Procurement, and Construction) contract signed with the Guinean government in January 2016 allows only 58 months for completion—17 months shorter than comparable domestic projects—with a peak concrete placement intensity of 200,000 m^3 per month.

Second, complex geological conditions requiring dynamic design adjustments. The overburden reaches maximum thickness of 45 m, slope heights up to 150 m, with water-softened rock and weak interlayers creating complex geological conditions that raise critical concerns about dam stability, safety, and investment, necessitating continuous design modifications.

Third, stringent construction environment with high design requirements. The contract explicitly mandates European and American standards, requiring design documents to pass multiple layers of review by YREC (design team), CWE (general contractor), CTEB (subcontractor), SECC (Chinese supervision), and TEF (French consultant). Bulk materials including cement, fly ash, steel, equipment, and spare parts must be imported with procurement and transportation cycles of at least six months, creating substantial schedule risks.

Fourth, limited design comprehension capability among construction personnel. Two-thirds of the construction workforce consists of local employees with low educational levels and poor professional skills, resulting in inadequate understanding of design intent.

2.1 BIM Application Objectives

To address these challenges, the project team decided to leverage the 3DE platform and independently developed design information management system to achieve real-time forward collaborative design across all project phases. This approach extends the design service chain to provide critical support throughout the project lifecycle, delivers digital engineering assets, and leverages the Belt and Road Initiative platform to promote Chinese elements, technology, standards, and quality on the international stage.

2.2 Implementation Plan

Given the project' s BIM application characteristics, BIM design was implemented across all phases from feasibility study through preliminary design to construction drawings. Before project initiation, we established BIM design stage division standards tailored to the water resources and hydropower industry. When model detail and design depth met the criteria for advancing to the next design stage, the system automatically progressed to the subsequent phase. This ensured model continuity rather than discontinuity throughout the design cycle, enhancing the continuous application and utilization efficiency of model deliverables. ENOVIA-based project management was conducted locally to manage human resources and design deliverables, with all design outcomes stored on cloud servers to ensure data traceability. For the construction site, we employed independently developed information management software for site document control, preventing management chaos of site design documents and elevating design information management standards.

2.3 Team Organization

To ensure successful and timely project delivery, the project was supervised by the company chairman, led by the chief engineer, and managed by the project manager. All BIM design team members were technical backbones from various professional disciplines who participated throughout the entire design process, possessing both extensive BIM theoretical knowledge and practical experience, thus avoiding the separation between design and BIM teams.

2.4 Application Measures

The successful implementation of BIM design for the Suapiti Hydropower Station project resulted from the team' s strict adherence to company BIM standards. The company compiled comprehensive BIM guidelines including the *3DE Collaborative Design Procedures*, *Geographic Location and Terrain Establishment Manual*, *Resource Library Management Manual*, *3D Review Process*, *Design Document Version Change Regulations*, and *3D Annotation and Engineering Drawing Standards*. These standards established strict requirements for design permission management, collaborative design platform construction, project document management, file version upgrades across different design stages, terrain and geological modeling, and 2D drawings, ensuring that the project could deliver construction-ready refined models, quantities, and synchronized drawing links throughout all phases, particularly during the construction drawing stage, providing technical guidelines for forward design implementation.

2.5 Software and Hardware Environment

On the software side, the project' s primary collaborative platform was Dassault Systèmes' latest 3DEXPERIENCE platform, an advanced design system built upon CATIA V5 with enhanced professionalism, efficiency, and scalability. Combined with commercial software such as CATIA V5, CATIA Composer, ANSYS, ABAQUS, and Visual Studio, independently developed interface programs enabled BIM information sharing.

On the hardware side, all BIM engineers were equipped with HP tower workstations featuring Intel(R) E3-1270 processors, NVIDIA Quadro P2000 graphics cards, 2$×$16GB DDR4-2400 memory, and 256GB solid-state system drives.

3.1 BIM Modeling

Across all phases—feasibility study, preliminary design, and construction drawings—multi-disciplinary real-time forward design was conducted on the 3DEXPERIENCE platform, covering planning, geology, hydraulic structures, powerhouses, construction, electromechanical systems, metal structures, and cost estimation. Model detail and complexity continuously evolved, with the complete model reaching 3.2 GB in storage size by the construction drawing stage.

During the feasibility study stage, primary work focused on dam type and alignment scheme comparison, using parametric models to rapidly establish dam shape models for different alignments and types. In the preliminary design stage, after finalizing the dam type and alignment, detailed processing was performed on the corresponding shape model to create detailed models incorporating electrical and metal structure equipment. The construction drawing stage continued with the detailed preliminary design model, implementing further refinement for precise dam foundation excavation design, rational concrete zoning, electrical equipment layout, pipeline design, and generating Bill of Materials (BOM) tables and final 2D construction drawings for implementation.

3.2 BIM Application Status

(1) Real-Time Forward Collaborative Design Based on 3DE Platform
Leveraging the 3DE platform enabled real-time online collaborative work across all disciplines. Knowledge base resources including templates and family libraries [2] resided on the server, ensuring data source uniqueness. Real-time access to the complete model enabled timely design progress control, while online user information management provided immediate insight into project human resource allocation. The 3DE platform' s collaborative design architecture is shown in Figure 4 [Figure 4: see original paper].

Current BIM applications mostly remain at the CAD-based modeling stage, which represents a transitional but positive phase in BIM development. Our application of forward design in water resources and hydropower engineering aims to unlock BIM' s true value [3-4]. The project' s forward design process primarily involved: establishing terrain and geological models based on 3D survey data; multi-disciplinary real-time online collaboration to create stage-specific BIM models; online design progress control and design-review-approval by project management; comprehensive dynamic design data control; and ultimately delivering drawings and construction guidance. The detailed design process is illustrated in Figure 5 [Figure 5: see original paper].

(2) Enterprise-Level Resource Library Development
We enhanced and expanded our enterprise-level resource library, developing standard civil engineering libraries and GB/IEC electromechanical libraries. To date, the library contains over 20,000 components and more than 400 standard parametric models, maximizing knowledge sharing across disciplines, reducing redundant work, and improving enterprise resource utilization.

(3) Intelligent Gravity Dam Design
Integrating design codes with the company' s proprietary knowledge engineering, we independently developed an intelligent gravity dam design program that standardizes and automates gravity dam design, enabling rapid completion. This program allows new engineers to quickly become productive while liberating experienced engineers from tedious drafting tasks to focus on innovative dam design.

(4) Complex Dam Foundation Excavation Optimization
In traditional excavation design near soil-rock interfaces, only simplified single slopes could be applied. Soil-based excavation yields gentle, conservative slopes, while rock-based excavation produces steep slopes that save 工程量 but compromise safety [5]. Using BIM technology, we achieved precise excavation near soil-rock interfaces, enabling real-time dynamic adjustment of geological models and excavation designs based on actual site conditions. This approach

ensures slope stability while optimizing 工程量. The dam foundation excavation method comparison is shown in Figure 6 [Figure 6: see original paper].

Specific optimization aspects include:

1) Spillway Bottom Outlet Dam Section Optimization
Using mutual validation among BIM models, CFD calculation models, and physical models, we identified insufficient aeration along flow channel side walls that would severely impact structure quality, safety, and service life. Through iterative model adjustments to meet aeration requirements, we ensured design safety and reliability. The optimization process is shown in Figure 7 [Figure 7: see original paper]. Due to complex structural geometry, we performed 3D reinforcement design for the dam body based on BIM models, finite element models, and 3D reinforcement models, achieving model sharing that improved design quality and efficiency. Reinforcement drawing production time was reduced from the traditional two months to one month, with design documents passing consultant review on the first submission.

2) Radial Gate Optimization Design
Gate equipment is manufactured in China and transported to the Guinea project site for installation. With design, manufacturing, and transportation requiring substantial time, any product issues requiring factory return would delay the schedule by at least six months at enormous cost. Using the resource library, we rapidly assembled gate BIM models and applied DMU motion simulation to resolve gate movement interference issues, ensuring gates met design requirements before shipment and guaranteeing schedule adherence. The optimization is shown in Figure 8 [Figure 8: see original paper].

3) Large Equipment Lifting Process Simulation
Rotor lifting represents a milestone in hydropower station electromechanical equipment installation. As the heaviest component (approximately 310t), the rotor' s placement location for pre-installation storage and maintenance requires precise structural calculation of the supporting beam system. Any positioning error could cause structural damage to the powerhouse. Additionally, the rotor lifting process must traverse the large stator frame, requiring pre-defined motion trajectories. Visual simulation of the rotor lifting process optimizes powerhouse spatial structure, saves 工程量, and guides owners and contractors in developing rotor lifting procedures, improving lifting precision and reducing operational errors [6]. The lifting simulation is shown in Figure 9 [Figure 9: see original paper].

4) BIM-Based Design Information Management System Development
Integrating BIM, internet technology, and advanced graphics rendering engines, we independently developed a design information management system that associates lightweight BIM models with site design documents, enabling interactive model queries and real-time updates. The system allows viewing lightweight models of design and construction progress at any moment, achieving digital delivery of design documents. It manages design drawings, site design logs,

weekly design change meetings, and other processes, gradually forming traceable big data that enhances overall project design management. The system interface is shown in Figure 10 [Figure 10: see original paper].

4 Application Effects

The collaborative forward design based on the 3DE platform ensured data source uniqueness, design optimization, and enabled design progress control and human resource management. Through this project, we enriched and improved our enterprise resource library, adding over 2,000 new library files for a total exceeding 20,000, with more than 400 standard parametric models. The intelligent gravity dam design program standardized and automated dam design, reducing design time by three months. The BIM-based design information management system standardized management of design information including drawings, changes, notifications, and calculation reports, improving overall project management and increasing communication efficiency by 70%. Dam foundation excavation optimization saved 238,000 m^3 of excavation, directly reducing investment by $1.5279 million and shortening excavation duration by three months. Optimization analysis of the dam body and gates saved one month of design time, gained four months on the schedule, and avoided six months of potential delays.

5.1 Innovations

(1) The project achieved multi-disciplinary real-time, online, collaborative forward design using the 3DE platform, ensuring data source uniqueness and design optimization. Real-time access to the latest complete design enabled comprehensive and timely design progress control, while online user information allowed immediate understanding of resource allocation and human cost consumption, creating an entirely new digital design workflow with full lifecycle data management.

(2) We independently developed an intelligent gravity dam design program that integrates design codes with proprietary knowledge engineering, achieving intelligent, standardized, and rapid design of water resources and hydropower projects.

(3) We independently developed and implemented a deliverable "BIM-based Design Information Management System,"providing a supportive platform and practical experience for BIM applications in water resources and hydropower engineering.

5.2 Lessons Learned

(1) The company' s existing BIM standard system still has deficiencies requiring further refinement. While 3D review offers strong advantages in detecting model collisions, it is less intuitive than CAD for checking specific

design details such as stationing, dimensions, and angles because CAD review includes extensive annotation references. Improving the convenience of 3D review requires further research.

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