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 Dassault Systèmes of France 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 leveraging ENOVIA, design deliverables were uniformly integrated on the 3DE platform, thereby ensuring the optimality and safety of design outcomes, improving product quality, and creating continuous deliverable digital engineering assets. Combined with secondary development of Composer, a design information management system was independently developed to perform lightweight processing of BIM models, facilitating on-site management of construction design documents associated with BIM models and enhancing the information management standards of hydropower station projects.

Full Text

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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 all design deliverables on the 3DE platform, the project ensured optimization and security of both the design process and outcomes, improved design product 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 management of site design documents associated with BIM models at the construction site and enhancing overall project information management 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, approximately 135 km from the capital, Conakry. The project features a total reservoir capacity of 7.489 billion m^3, installed capacity of 450 MW, and annual generation of 2 billion kWh. Classified as a Grade I project with large-scale (Type 1) classification, 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. The project rendering is shown in Figure 1 [Figure 1: see original paper], the BIM model in Figure 2 [Figure 2: see original paper], and the 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]:

(1) **Tight schedule and heavy workload.** The F+EPC (Finance + Engineering, Procurement, and Construction) contract was signed with the Guinean government in January 2016, allowing only 58 months for completion—17 months shorter than comparable domestic projects. The peak monthly concrete placement intensity reaches 200,000 m^3.

(2) **Complex geological conditions requiring dynamic design adjustments.** The overburden layer reaches a maximum thickness of 45 m, with slope heights up to 150 m. Rock softens when exposed to water, and weak interlayers are present. These complex geological conditions create prominent issues regarding dam stability, safety, and investment, necessitating dynamic design adjustments.

(3) **Stringent construction environment with high design requirements.** The contract explicitly requires adoption of European and American standards, and design documents must pass through 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 all be imported, with procurement and transportation cycles requiring at least 6 months, creating substantial schedule risks.

(4) **Insufficient capability of construction personnel to understand design intent.** Two-thirds of the construction workforce consists of local employees with low educational levels and poor professional skills, limiting their ability to comprehend design intentions.

2.1 BIM Application Objectives

To address these challenges, the project team decided to rely on 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, enables deliverable digital engineering assets, and leverages the "Belt and Road" strategic platform to promote "Chinese elements," "Chinese technology," "Chinese standards," and "Chinese quality" on the international stage.

2.2 Implementation Plan

In response to the project' s BIM application characteristics, BIM design was implemented across all stages from feasibility through preliminary design to construction drawings. Before project initiation, research was conducted to establish BIM design stage division standards appropriate for the water resources and hydropower industry. When model detail and design depth satisfy conditions for design stage transition, the program automatically determines and advances to the next stage. Within the design cycle, models are not intermittent but maintain continuity, thereby enhancing continuous application and utilization efficiency of model deliverables. Project management is conducted locally based on ENOVIA, managing human resources and design deliverables, with all design 成果 stored on cloud servers to ensure data traceability. For the construction site, an independently developed information management program manages site documents, avoiding confusion in on-site design document management and elevating design information management standards.

2.3 Team Organization

To ensure successful project delivery, the project is overseen by the company chairman, managed directly by the dean of the engineering academy, and executed by the project manager. All BIM design team members are technical backbones from various professional design disciplines who participate throughout the entire design process and possess extensive BIM theoretical knowledge and practical experience, preventing separation between design and BIM teams.

2.4 Application Measures

The successful implementation of BIM design for the Suapiti Hydropower Station project stems from the team' s strict adherence to company BIM standards. The company has compiled comprehensive BIM standards 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 Specifications*. These standards impose strict requirements on 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 achieves constructible refined models, engineering quantities, and synchronized drawing links throughout all stages, particularly during the construction drawing phase, thereby providing technical guidelines for forward design.

2.5 Software and Hardware Environment

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

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

3.1 BIM Modeling

Across all stages—feasibility, 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 deepened across stages, with the complete model reaching 3.2 GB in storage size by the construction drawing stage.

During the feasibility stage, primary work focused on dam type and alignment scheme comparison, using parametric models to rapidly establish different dam alignment and type configurations. In the preliminary design stage, after finalizing the dam type and alignment, the corresponding configuration models were processed in detail to create comprehensive models incorporating electrical and metal structure equipment. The construction drawing stage continued from these detailed models, implementing further refinement for precise foundation excavation design, rational concrete zoning, electrical equipment layout, pipeline design, generating BOM tables for engineering quantities, and ultimately producing 2D construction drawings for implementation.

3.2 BIM Application Status

(1) **Real-time Forward Collaborative Design Based on 3DE Platform.** The 3DE platform enables real-time online collaborative work across all disciplines. Template and family library [2] resources reside on the server, ensuring data source uniqueness. Real-time access to the complete model enables timely design progress control, while online user information management provides 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 phase in BIM development with positive contributions. Our application of forward design with BIM in water resources and hydropower engineering aims to unlock BIM' s true value [3–4]. The project' s forward design process primarily involves: 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 review by project management, comprehensive dynamic design data control, and ultimately achieving drawing production and construction guidance. The specific design process is shown in Figure 5 [Figure 5: see original paper].

(2) **Enterprise-level Resource Library Construction.** The enterprise-level resource library has been perfected and enriched, expanding common civil engineering libraries and establishing standard GB/IEC electromechanical libraries. To date, the library contains over 20,000 parts and more than 400 standard parametric models, maximizing knowledge sharing among professional departments, reducing duplicate work, and improving enterprise resource utilization.

(3) **Intelligent Gravity Dam Design.** Integrating design specifications 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 proficient while liberating experienced engineers from tedious drafting tasks to focus on innovative gravity dam design.

(4) **Complex Foundation Excavation Optimization.** In traditional excavation design near soil-rock interfaces, only simplified single-slope excavation was possible. Excavation based on soil layers results in gentle, conservative slopes, while rock-based excavation produces steep slopes that save 工程量 but compromise safety [5]. Using BIM technology enables precise excavation near soil-rock interfaces, allowing real-time dynamic adjustment of geological models and excavation designs based on actual

site conditions. This ensures both slope stability and 工程量 optimization. The comparison of foundation excavation methods is shown in Figure 6 [Figure 6: see original paper].

Specific applications include:

1) **Spillway Bottom Outlet Dam Section Optimization.** Using BIM models, CFD calculation models, and physical models for mutual verification revealed insufficient aeration along flow channel side walls, which would seriously affect structure quality, safety, and service life. Through iterative model adjustments until aeration requirements were satisfied, design safety and reliability were ensured. The optimization process is shown in Figure 7 [Figure 7: see original paper]. Due to complex structural geometry, 3D reinforcement design was performed 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 2 months to 1 month, with design documents passing consultant review on the first submission.

2) **Radial Gate Optimization Design.** Gate equipment is manufactured in China, transported to the Guinea project site for installation, with long design, manufacturing, and transportation cycles. Any product issues requiring factory return would delay the schedule by at least 6 months at enormous cost. Using the resource library, gate BIM models were rapidly assembled and DMU motion simulation resolved gate movement interference issues, ensuring gates met design requirements before shipment and guaranteeing schedule achievement. The optimization is shown in Figure 8 [Figure 8: see original paper].

3) **Large Equipment Lifting Process Simulation.** Rotor lifting in hydropower stations represents a milestone in electromechanical equipment installation. As the heaviest component (approximately 310t), the rotor' s placement position for pre-installation and unit maintenance requires precise calculation of the supporting beam structure based on equipment weight. Any position deviation could damage the powerhouse structure. During rotor lifting, crossing the large stator frame requires predetermined motion trajectories. Visual simulation of the rotor lifting process optimizes powerhouse spatial structure, saves 工程量, guides owners and contractors in developing rotor lifting procedures, improves lifting precision, and reduces 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 viewing of lightweight models showing design and construction progress at any mo-

ment. The system achieves digital delivery of design documents, manages design drawings, design change notifications, calculation sheets, and weekly design change meetings, 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, scheme optimization, and enabled design progress control and human resource management. Through this project, the enterprise resource library was enriched and perfected with over 2,000 new library files, bringing the total to the 20,000 level with more than 400 standard parametric models. The intelligent gravity dam design program was developed, standardizing and automating gravity dam design to reduce design time by 3 months. The BIM-based design information management system standardized management of design information including drawings, changes, notifications, and calculation sheets, improving overall project management and increasing communication efficiency by 70%. Foundation excavation optimization saved 238,000 m^3 of excavation, directly reducing investment by $1.5279 million and shortening excavation duration by 3 months. Optimization analysis of the dam body and gates saved 1 month of design time, gained 4 months on the schedule, and avoided 6 months of potential delays.

5.1 Innovations

(1) The project achieved multi-disciplinary real-time, online, collaborative, forward design based on the 3DE platform, ensuring data source uniqueness and design scheme optimization. Real-time access to the complete latest design product enables comprehensive and timely design progress control, while online user information management provides immediate insight into project resource and labor cost consumption, creating an entirely new digital design workflow with full-process data management.

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

(3) We independently developed and deployed a deliverable "BIM-based Design Information Management System," providing a supportive platform and practical reference 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 provides extensive annotation references. How to make 3D review more convenient requires further research.

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