KEY TECHNICAL ISSUES AND RESEARCH WORK IN YALONG RIVER HYDROPOWER DEVELOPMENT

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HIGHLIGHTS

I. HYDROPOWER RESOURCES OF THE YALONG RIVER
II. DEVELOPMENT STRATEGY AND PROGRESS
III. KEY TECHNICAL ISSUES
IV. RESEARCH WORK
V. PROGRESS IN RESOLUTION OF THE KEY ISSUES
VI. CONCLUSION AND EXPECTATIONS
I. HYDROPOWER RESOURCES OF THE YALONG RIVER
I. HYDROPOWER RESOURCES OF THE YALONG

- Originates in Qinghai Province, passes through Sichuan, and joins the Jinsha River.
- River length: 1,571km
- Natural head: 3,830m
- Catchment area: 136,000km²
- Annual runoff: 61 billion m³
I. HYDROPOWER RESOURCES OF THE YALONG

- 21 cascade projects planned
- Technical developable capacity: 30,000MW, 24% of Sichuan or 5% of China
- Technical developable annual generation: 150TWh
- Ranking 3rd among China’s 13 hydropower bases
I. HYDROPOWER RESOURCES OF THE YALONG

The Upper Reach

- Upstream of Lianghekou, 688km
- 9 cascade projects, 2,500MW

Longitudinal Section of the Cascade Stations along the Yalong River
I. HYDROPOWER RESOURCES OF THE YALONG

The Middle Reach

- Lianghekou to Kala, 385km
- 7 cascade projects, 11,505MW
- Lianghekou has a multi-year regulating reservoir
I. HYDROPOWER RESOURCES OF THE YALONG

The Lower Reach

- Kala to confluence, 412km
- 5 cascade projects, 14,700MW
- Jinping-I has a yearly-regulating reservoir
I. HYDROPOWER RESOURCES OF THE YALONG

In the Middle & Lower Reaches

- large-size projects
- small inundation losses
- simplex development purpose
- substantial scale advantages
- excellent cascade compensation benefits
I. HYDROPOWER RESOURCES OF THE YALONG

- When formed, a regulating storage of 14.84 billion m$^3$
- When joint operated, multi-year regulating capacity
II. DEVELOPMENT STRATEGY AND PROGRESS
Stage 1

**Before 2000:**
Complete Ertan Hydropower Station to achieve a capacity of 3,300MW

The ‘4-stage’ Development Strategy
II. DEVELOPMENT STRATEGY AND PROGRESS

Stage 2

Before 2015:
Complete lower reach stations of 11,400MW to raise the total capacity up to 14,700MW

Jinping-I 3,600MW
Jinping-II 4,800MW
Guandi 2,400MW
Ertan 3,300MW
Tongzilin 600MW

The ‘4-stage’ Development Strategy
II. DEVELOPMENT STRATEGY AND PROGRESS

Stage 3

Before 2020:
Add 8,000MW of new capacity to raise the total capacity up to 23,000MW.

Lianghekou 3,000MW
Yangfanggou 1,500MW
Kala 980MW
Before 2030:

Complete all remaining projects to reach the total capacity of 30,000MW.

II. DEVELOPMENT STRATEGY AND PROGRESS

The ‘4-stage’ Development Strategy

Stage 4

Valley development complete
II. DEVELOPMENT STRATEGY AND PROGRESS

Development Progress

- Lower reach: Construction works going on well, with units put into service in succession since 2012
- Middle reach: Preparatory works underway
- Upper reach: Preliminary works for main projects started
III. KEY TECHNICAL ISSUES
Yalong River Basin lies in steeply cut deep gorges, with complex geological conditions.

**World-class Projects**

- **Jinping-I**: World’s highest dam of 305m
- **Jinping-II**: World’s largest hydraulic tunnel group with great overburden
- **Lianghekou**: Super-tall rockfill dam of 300m
III. KEY TECHNICAL ISSUES

1. High dam design theory and methods

2. Stability and treatment of high and steep slopes in complex geology

3. Safety of the deeply buried, long and large diameter tunnel group

4. Real-time control and management of the construction process

5. Optimized joint operation of cascade stations

6. Environmental benefits and engineering measures
Increase in dam height from 200m to 300m makes the structural safety of a dam and its flood discharge capacity disproportionately more demanding.
Excavation of Jinping-I dam foundation and abutment formed steep slopes some 535m in height;

Faults and joints in the left bank made the job more challenging.
3. Safety of Deep, Long & Large Tunnel Group

- 4 headrace tunnels, 2 access tunnels, 1 drainage tunnel
- Max. overburden: 2,525m
- Large overburden, long length, large diameter (13m)
- World’s largest hydraulic tunnel group
III. KEY TECHNICAL ISSUES

Issues Faced in Tunnel Construction

- Rock burst under high stresses (up to 70MPa)
- High-pressure water gushes (e.g. maximum initial inflow at a single point reached an incredible 3.73 m³/s)
- Construction ventilation
- Fast TBM boring and mucking
- Load relief and deformation during excavation of huge powerhouse caverns
III. KEY TECHNICAL ISSUES

4. Real-time Control of Construction Process

Scattered layout of construction facilities made management and communication rather difficult.
III. KEY TECHNICAL ISSUES

5. Optimized Joint Operation of Cascade Stations

With 21 stations, optimized approach to joint operation management of the stations is imperative.

For such a large basin

No precedent in China

Lack of theoretical preparedness and practical experience

Operation modes of the primary cascade stations call for detailed and in-depth studies.
III. KEY TECHNICAL ISSUES

6. Environmental Benefits and Engineering Measures

- Study the impact on the ecology against the benefits of basin development.
- Establish quantification methods and criteria for appraisal of environmental impacts.
- Mitigate adverse impacts on environment by means of engineering measures.

Impact on the environment is one of the key issues requiring valid and acceptable solutions.
IV. RESEARCH WORK
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Established a research fund with the National Natural Science Foundation of China to finance research forces from across the Nation.

Co-operation with high-end research platforms ensured substantial resolution of the key issues.

Cooperated with China’s best-known universities and research institutes to study the issues.
1. High Dam Design Theory and Methods

Research work in application of fundamental theories and innovative technologies

- arch dam realistic working and behavior simulation
- high performance mass concrete
- spillway dissipation technology for 300m high dams
- testing of earth/rock material under complex loading conditions
- arch dam failure mechanism & safety assessment
- hydraulics of high-head & large-flow spillway tunnels
- high rockfill dam deformation analysis & safety control
IV. RESEARCH WORK

1. High Dam Design Theory and Methods

- Arch dam mechanics test and stability study
- Spillway dissipation test
- Dam concrete test
- Dam foundation reinforcing measures

- Dam materials and structural study
- Seepage properties and control measures

Jinpeng-I

Lianghekou
IV. RESEARCH WORK

2. High Slope Stability and Treatment

- Dynamic mechanical process for development of high slopes in the Yalong Basin, and their engineering adaptability evaluation
- Analytical methods for deformation and stability of complex high and steep slopes in China’s South-west
- Pre-warning and preventive measures for large slides of high rock slopes triggered by loss of stability
- High slope monitoring and warning system to monitor steep slope construction activities
IV. RESEARCH WORK

3. Safety of Deep, Long & Large Tunnels and Tunnel Group

- Theoretical and experimental research in engineering properties of deep-buried rock mass
- Development of stress-detecting robots
- Forecasting and treatment of high-pressure large-flow underground water and adverse geological conditions
- Forecasting and stability analysis of the large headrace tunnels and power house caverns
IV. RESEARCH WORK

3. Safety of Deep, Long & Large Tunnels and Tunnel Group

- Comprehensive rock burst prevention system
- Geological forecasting & grouting technology for sealing-off high-pressure water
- TBM construction and conveyor systems, and long tunnel ventilation technology
- Stability study of power house caverns

Based on above work:
4. Real-time Control and Management of Construction Process

IT-aided Construction Management

- Real-time control and management of construction process
- Fast integration of important data for real-time control of construction process by means of GPS technology
- A real-time control system developed to aid management of construction quality and progress
- For Jinping-I, a system was developed for automatic control of dam concrete temperature
IV. RESEARCH WORK

5. Joint Operation of Cascade Stations

- Power plant dispatch modes
- Joint operation models and methods
- Jinping-II transitional process and constraining conditions
- Real-time monitoring system of Jinping-I and Guandi spillway dissipation safety
- Coupled vibration properties of generator units and their operation methods
6. Environmental Benefits and Engineering Measures

Study of Environment Benefits and Impact

- Environmental impact assessment
- Design of multi-level water intake structure
- Study of standard for ecological flows
- Study of fish hatch & release technology
- Planting technology improved restoration of the vegetation
V. PROGRESS IN RESOLUTION OF THE KEY ISSUES
1. High Dam Design and Real-time Construction Control

- Structural design of Jinping-I mostly finalized
- Slit-type bucket adopted for surface & low-level dam outlets to extend the nappe for collision avoidance
- Dovetail bucket used for tunnel spillways
For dam concrete, coarse aggregate of quartzitic sandstone and fine aggregate of marble were used.

Dam concrete construction quality has been closely controlled.
1. High Dam Design and Real-time Construction Control

Key design & construction issues for super-high arch dam basically solved
2. High Slope Stability and Treatment

- Excavation and support of Jinping-I high slopes all completed by 2008.
- After reservoir filling, monitoring data show that slope deformation is well within the safety range.

anchoring work of left bank slope above El.1,885m
V. PROGRESS IN RESOLUTION OF KEY ISSUES

3. Construction of Deep, Long & Large Tunnels and Safety of Tunnel Group

- Comprehensive rock burst prevention mechanism;
- Forecasting methods;
- Underground water handling approaches;
- Fast TBM boring technology;
- Long tunnel ventilation technology;
- Rapid construction monitoring and feedback to direct dynamic design, etc.
4. Optimized Joint Operation of Cascade Stations

- Remote-controlled from the control center in Chengdu;
- Benefit from joint operation begins to emerge;
- An initial stage of joint operation achieved.
Engineering measures taken concurrently with project construction;

- Multi-level water-take structure for Jinping-I constructed to ensure proper temperature of the water released to the downstream of the river;

- Jinping-II operated adopting usual criteria for the release of ecological flows;

- Jinping-Guandi Fish Hatchery in good operation.

Fish fry being released to the river.
VI. CONCLUSION AND EXPECTATIONS
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Hydropower development of the Yalong River is already in an expedited stage.

Key technical issues have been basically resolved.

An optimized pattern for joint operation of multiple stations is gradually taking shape.

Design and control of high earth-core rockfill dams will become the focus of further research.
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Thank you!