DEVELOPMENT OF CASCADE HYDROPOWER PROJECT IN NAM OU RIVER BASIN IN LAOS ALONG BELT &ROAD BY POWERCHINA

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1 BACKGROUND AND PLANNING

Laos, the mountainous and land-locked south-east Asian nation with abundant hydropower resources, aims to make Laos the battery of Southeast Asia. It has supported the hydropower development by introducing international capital and expertise, thus keeps translating the abundant hydropower potential to economic advantages by exporting to neighboring countries and catering to the growing internal demand at the same time. In the 1990s, numerous planning schemes were put forward by internationally renowned companies adopting the traditional high dam proposal with higher installed capacity and better economic gains. However, those were declined by the government of Laos because of enormous submerged area, large scale of relocation, insufficient consideration of the environment preservation and the resettlement recovery.

To properly harness the hydraulic resources of Nam Ou River, minimize the inundation loss and reduce impact on the environment, an innovative and scientific scheme of "One Reservoir and Seven Cascades" was proposed after a lot of further technical studies of the topographical and geological conditions and the project layout was carried out. Therefore, the immigration population reduced from 57,000 to 11,570, the local culture heritage and indigenous resources were kept intact to the fullest extent, the local livelihood improved by increased job opportunity and upgraded infrastructure, shaped a well-integration of native prosperity and project success. It won unanimous recognition of Lao government and local societies.

The final Planning Scheme is given as follow:

Figure 1 Layout of the Nam Ou HPP

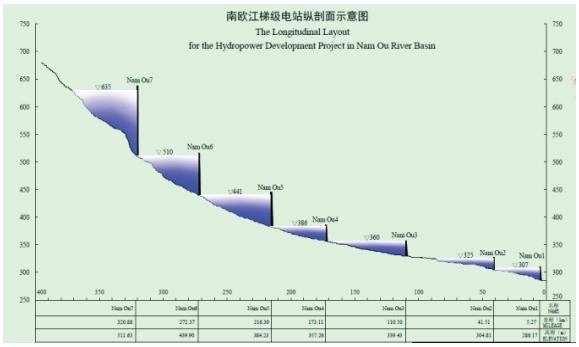

Figure 2 Longitudinal Layout of Nam Ou HPP

2 INTRODUCTION OF PROJECT

2.1 Brief

Nam Ou River, the largest tributary on the left bank of the Mekong River in Lao PDR, flows 475 kilometers southward to LuangPrabang Province. With a drainage area of 256,000 square kilometers and an approximately 430m water drop, the Nam Ou River Basin Cascade Hydropower Project (Nam Ou HPP) is developed by POWERCHINA on the basis of BOT mode, with 29 years of concession period (excluding construction period). The total install capacity is 1272 MW and total investment cost is 2.74 billion USD. The project has been developed by two phases.

2.2 Hydropower Project at Phase I

Hydropower Project at Phase I includes the development of second-cascade, fifth-cascade and sixth-cascade hydropower stations with total installed capacity of 540MW. It has been in operation for 3 years and has generated over 2.7 billion kWh reliable power to the north of Laos by the end of 2019.

The installed capacity of the second cascade hydropower station is 3×40MW, the maximum height of the gate dam is 52m, the normal storage water level is 325m, the total storage capacity is 0.122billion m^3, the average annual generation is 0.484 billion kwh .The construction works are mainly composed of gate dam, riverbed-type powerhouse and stilling basin etc..

The installed capacity of the fifth cascade hydropower station is 3×80MW, the maximum height of concrete gravity dam is 74m, the normal storage water level is 441m, the total storage capacity is 0.335billion m^3, and the average annual electricity generation is 0.977 billion kwh .The construction works are mainly composed of concrete gravity dam, powerhouse at the dam-toe and non-overflow dam section etc..

The installed capacity of the sixth cascade hydropower station is 3×60MW, the maximum height of the Composite Geomembrane Face Full Section Soft Rock Rock-fill Dam is 85m, the normal storage water level is 510m, the total storage capacity is 0.409 billion m^3, the average annual electricity generation is 0.726 billion kwh. The construction works are mainly composed of geomembrane face rock-fill dam, ground-type powerhouse, spillway etc..

Figure 3 Sketch of Hydropower Project at Phase I

2.3 Hydropower Project at Phase II

Hydropower Project at Phase II includes the development of first-cascade, third-cascade, fourth-cascade and seventh-cascade hydropower stations with total installed capacity of 732MW. It is scheduled to run into commercial operation in 2020.

The installed capacity of the first cascade hydropower station is 4×45MW, the maximum height of the gate dam is 52.5m, the normal storage water level is 307m, the total storage capacity is 0.118 billion m^3, the average annual electricity generation is 0.709 billion kwh .The construction works are mainly composed of concrete gate dam, riverbed type powerhouse and non-overflow dam section etc..

The installed capacity of the third cascade hydropower station is 3×70MW, the maximum height of the concrete gravity dam is 59.5m, the normal storage water level is 360m, the total storage capacity is 0.218billion m^3, the average annual electricity generation is 0.811 billion kwh .The construction works are mainly composed of concrete gravity dam, riverbed type powerhouse and non-overflow dam section etc..

The installed capacity of the fourth cascade hydropower station is 3×44MW, the maximum height of the gate dam is 60.25m, the normal storage water level is 386m, the total storage capacity is 0.142billion m^3, the average annual electricity generation is 0.487 billion kwh .The construction works are mainly composed of gate dam, non-overflow dam section etc., discharge structure.

The installed capacity of the seventh cascade hydropower station is 2×105MW, the maximum height of the concrete faced rock-fill dam is 143.5m, the normal storage water level is 635m, the total storage capacity is 1.77 billion m^3, the average annual electricity generation is 0.84 billion

Kwh .The construction works are mainly composed of concrete faced rock-fill dam, ground powerhouse, spillway etc..

Figure 4 Sketch of Hydropower Project at Phase II

For the seven cascades of the Nam Ou HPP, different types of dam were adopted due to different terrain, geological, scale and flood discharge conditions. The dam type of the first-cascade, second-cascade, fourth-cascade hydropower stations is unanimously Gate Dam. The third-cascade, fifth-cascade hydropower stations are of concrete gravity dam. Composite Geomembrane Faced Soft-rock-fill Dam is applied in the sixth-cascade hydropower station. The seventh–cascade hydropower station is of Concrete Faced Rock-fill Dam. Different dam implies different material, structure, stress distribution, flood discharge mode and construction method.

POWERHINA, as an experienced international contractor and developer, covers the whole industry chain from hydropower investment, design, manufacture, construction to operation. It gave full play to the inherent advantage of resources aggregation, enhanced cooperation with industry, university and research institute. Through holistic planning and design, carrying out technology research and management innovation, the Nam Ou HPP overcame countless technical difficulties and problems. As the first overseas river-basin development project by Chinese enterprise, it has set a typical example for overseas river-basin development.

Table 1 : Main Parameters of Each Cascade Hydropower Project

SN.	Item	Unit	First	Second	Third	Fourth	Fifth	Sixth	Seventh
1	Drainage Area	km^2	25500	22200	19110	11660	10270	5480	3448
2	Multi-year average flow at the dam site	m^3/s	588	513	436	299	274	160	104

3	Normal reservoir level	m	307	325	360	386	441	510	635
4	Installed Capacity	MW	180	120	210	132	240	180	210
5	Multi-year average power generation	10^8 kWh	7.09	4.84	8.11	4.87	9.77	7.26	8.4
6	Dam Type		Gate Dam	Gate Dam	Concrete Gravity Dam	Gate Dam	Concrete Gravity Dam	Geomembrane faced Rock-fill Dam	Concrete faced Rock-fill dam
7	Dam Height	m	52.5	52	59.5	60.25	74	85	143.5

3 KEY INNOVATION OF DESIGN & CONSTRUCTION

Overseas investment is complicated due to its susceptible to external uncertainties, demanding top-level design and expertise & advanced wits. POWERCHINA promoted close cooperation on the basis of complementary advantages, forming a united team through resources aggregation. By focusing on the project quality, schedule, safety, cost and environment protection, the concerted efforts contributed to the successfully implementation of hydropower project at Phase I.

3.1 Systematic Advantage and Design Optimization

With the Nam Ou HPP developed by two phases, the experiences and lessons of the Hydropower Project at Phase I were timely summarized and provided a conducive and convenient reference to the Hydropower Project at Phase II. It guided the design optimization of the second phase project, avoided design defect, improved efficiency, saved time and cost, and promoted quality and safety. Regulations on design optimization were formulated. Reasonable optimization was encouraged and rewarded under the precedent that the safety and function of the project secured. Regular negotiation meetings were held to discuss key technical issues, design proposals and construction methods.

Independent test in Laos is neither obligatory nor precedent due to the lacking of local test and inspection body equipped with full set of professional equipment and instrument in hydropower industry. But to improve quality control over experiences of Hydropower Project at Phase I, Test and Inspection Center of the Nam Ou Hydropower Project at Phase II was established in the year of 2017. It was established to check tests made by the contractors, to test and inspect on-site raw materials, semi-finished products and engineering entities, to provide services such as geophysical prospecting, concrete performance test, etc., to handle on-site quality accidents and coordinate quality disputes and to support innovations related to new materials and technologies for the Nam Ou HPP.

The third installment river closure of the third-cascade hydropower station was planned with design flow of 356m^3/s, in which case the maximum drop shall reach 10.75m. The large inflow and deep water in the restricted layout may give rise to rapid surge, placing stringent requirements for rock cage quality and dumping intensity. To tighten risk control by fully tap the advantage of the cascade project, the discharge of the fifth-cascade was controlled half a month before the closure and limited to only 33m^3/s of ecological flow one week ahead. The well calculated plan and integrated close cooperation between the upstream and downstream led to successful river closure finally

3.2 Technology Innovation

3.2.1 *The Bulb Tabular Turbine in the High Head Study*

Bulb tabular turbine is usually applied in low head water hydropower project. Water-heads of the first-cascade, second-cascade, fourth-cascade hydropower stations vary between 20~30m, that of the fourth-cascade hydropower station reached as high as 28m, which goes beyond the historical record and the commonly accepted level after specific research was carried out in design.

Comparisons of the unit size, weight, dimension, flow efficiency were conducted between the Kaplan turbine and the Bulb Tabular Turbine. It was found that the water-head of the Bulb Tabular Turbine is higher with the same turbine diameter. To increase the water head of bulb tabular turbine, it is necessary to improve the runner blade design method and enhance energy and cavitation coefficient performance. Research on installation and maintenance of the bulb tabular turbine were carried out as well. Bulb tabular turbine was finally utilized in the fourth-cascade hydropower station based on the experiment data and the actual hydrological and dam site condition, set a new high water-head record of bulb tabular turbine in Asia. The total weight was 40 t less than the Kaplan turbine of the same rated capacity, the water consumption was reduced by around 4.85 percent, hydraulic characteristics such as specific speed and optimum efficiency were greatly improved with savings about 5.8million USD, which turned the research results into tangible technical and economic benefits.

3.2.2 *Application of Limestone Powder in Hydraulic Concrete*

Fly ash, a commonly used admixture of concrete, was scarce in the Laos market. Fly ash import requires transnational long-distance transportation and going through complicated customs clearance procedures, imposing risks on schedule and costs. Research and experiment on the application of limestone powder, another kind of concrete admixture which can be processed from local materials in the vicinity of the project with simple equipment at low cost, was carried out in the fifth-cascade hydropower station.

Experimental studies of different fineness and different dosage of limestone powder on the aggregate alkali activity effects and temperature control etc. were conducted. It underlined the production equipment and technology of limestone powder, provided a new way to inhibit alkali aggregate reaction, optimized the mix ratio of concrete to meet the design requirement. Temperature control measures were put forward to ensure that the crack resistance meets the design requirements. The production control index and inspection standard of limestone powder were established.

It was for the first time that limestone powder thoroughly replaced fly ash both in the RCC and normal concrete in the same project. The cost saving of Hydropower Project at Phase I is about USD 1.2 million to compare with using fly ash from Vietnam, about USD 2.24 million to compare with fly ash from China.

3.2.3 *Application of CSGR in the Longitude Cofferdam*

The fifth-cascade hydropower station confronted challenges such as huge cofferdam quantity, inconvenient access and material exploitation. Since Cemented Sand, Gravel and Rock (CSGR) is characterized by utilization of local materials, cost saving, quick construction, environmental-friendly, to meet the flood control target, research and application of CSGR in the longitudinal cofferdam of the fifth-cascade hydropower station was conducted.

Through rational zoning, cushion thickness optimization, vibrated group-enriched CSGR, section type was put forward to suit the local topography and geological conditions, to be technically reasonable, convenient for construction. The CSGR longitudinal cofferdam of Nam Ou 5 HPP is the highest (45m) and the steepest comprehensive slope (1:0.7). In response to the unbalanced sand, gravel and rock distribution and sand ratio wide range fluctuation, materials from different sources were mixed together with fly ash (30%) and high efficiency retarding water reducer added, hence construction method and mixing ratio for CSGR cofferdam was formed, finally. The construction process was optimized by introducing measures of stepped section, large formwork, non-stop concentrated mixing, layered continuous paving and rolling. Appropriate grouting quantity was proposed and the construction method of vibrated group-enriched CSGR anti-seepage layer was put forward. Construction quality control indexes were put forward to ensure the quality, safety and progress of the CSGR longitudinal cofferdam during construction.

The research result was promoted to the first-cascade and fourth-cascade hydropower stations as well. The total cost saving is about 8Million USD, contributing to the project construction ahead of schedule, reduced land expropriation and material sources disposal. The technical, economic and environment benefits are remarkable and the prospects for promotion and application are wide.

3.2.4 *Geomembrane Face Soft Rockfill Dam*

Formation lithology of the sixth-cascade hydropower station dam site is mainly calcareous slate with a few of metamorphic siltstone. The average wet compressive strength of calcareous slate in dam site is 13.18 MPa, and softening coefficient is 0.59. To avoid adverse impact brought by the full section soft rock on the concrete face, five types of dams were compared during feasibility study phase. Based on the physical and mechanical properties of slate rock-fill and composite geo-membrane, research was made on the durability of geomembrane, anti-sliding stability, deformation adaptability and operation safety of the dam, uncovered composite geomembrane was for the first time applied on the surface anti-seepage of rock-fill dam of 100m Class. A new dam structure of uncovered Composite Geomembrane Face Rock-fill Dam was put forward.

Figure5 Uncovered Composite Geomembrane Face Rock-fill Dam

Systematic study on geomembrane materials, supporting layer structure, anchoring structure and surrounding connection structure was carried out. The connection between geomembrane and surrounding structure was optimized. The optimum mix ratio and structure of extruded curbs that both meet strength and water permeability requirements was identified. Mechanical anchoring system connecting geomembrane with extruded curbs was established. Systematic design and construction for the composite geomembrane seepage control system were established for the first time. The anchorage belt was installed layer by layer following the rise of the extruded curbs forming interlock construction, reserved reverse drainage pipe at the toe of the dam, thus forming the first domestic composite geomembrane face rock-fill dam construction method in the hydropower industry. Sound dam security monitoring system, operation and maintenance management method of geomembrane were established. Long-term safety evaluation and protection method of geomembrane anti-seepage system was proposed. The dam of the sixth-cascade hydropower station is the highest uncovered composite geomembrane rock-fill dam (85m) with the highest soft rock filling rate (81%) worldwide.

Since the project impoundment in 2015, the dam runs well with the deformation and seepage flow of the dam lower than the design value. It provided a practical successful example of design and construction of Composite Geomembrane Face Soft Rock Rock-fill Dam, offered a new choice of dam type especially in the material scarce areas.

3.2.5 *Concrete Faced Rock-fill Dam*

The material sources of the seventh–cascade hydropower station are complicated and the lithologic phase change significantly especially on the left bank quarry. The inter-bedded sand and mudstone are prone to weathering under the local high temperature and high humidity environment, easy to be crushed and segregated in the process of transport and filling, giving rise to the risks of sponge zone and void. Uneven settlement and seepage may further deteriorate the safety of the concrete faced rock-fill dam. Fine material selection and quality behavior control are of vital importance, of which whole process digital tracking from the quarry to the filling was made for uninterrupted close surveillance to ensure quality traceable and under control. The right selection of the foundation treatment measures, the concrete panel casting time, the mix ratio, the seepage and crack control of the concrete panel were systematically studied. Besides the dam security monitoring, three-dimensional finite element study on the settlement was conducted and provided instruction for the dam construction.

3.3 Automatic Hydrological Forecast System

Nam Ou river basin is typically mountainous, the monsoon floods leading to steep rise and fall. With only the seventh-cascade hydropower station has annual regulation capacity and the

fifth-cascade hydropower station seasonal regulation capability, flood control is essential for Nam Ou HPP. The density of hydrological network is low and hydrological data sequence is rather short. To be timely informed of the exact hydrological information, to improve the forecast precision and shorten prediction time, the hydrological stations were built and hydrological network supplemented. Flow models were established and automatic hydrological forecast system was put into operation. To guard against abrupt and raging flood, contingency plan and all-round inspection were specifically made, hidden danger spots identified and rectified, traffic road and drainage facilities cleared of obstruction. With the approach of the flood season, 24 hours duty mechanism initiated, flood alert disseminated prudently at the earliest, flood relief materials put in place, emergency rescue service drilled. Dam break impact of the seventh–cascade hydropower station on the downstream sixth–cascade hydropower station was assessed for the safety management. Furthermore, in response the growing concern of the Laos over safety of hydropower projects, successive dam break assessment of the whole Nam Ou River Basin is under way.

As market-oriented and demand driven, the Nam Ou HPP has made great strides in science and technology innovation. New materials tried, new workmanship utilized, new technology introduced, new equipment applied. All these efforts facilitated to solve technical problems, reduced project cost, guaranteed the construction schedule, achieved good social and economic benefits and won numerous science and technology prizes of Chinese National Committee on Large Dams and the China Society for Hydropower Engineering. By concerted efforts of all the parties, the scientific achievements were translated to realistic productivity, Hydropower Project at Phase I run into commercial operation on schedule. Hydropower Project at Phase II drawing on the accumulated experiences, is progressing smoothly..

4 OPERATION PRACTICE

Since commercial operation, Hydropower Project at Phase I focused on generating capacity, electric tariff, safety, efficiency and responsibility of the project. POWERCHINA, by carrying out standardization, informatization and intensification construction, positively responded to the adverse effects of load limitation, grid un-stability, insufficient power consumption, meticulously worked out production plans, strengthened load management and electricity charge recovery. To this date, the three hydropower stations of the Hydropower Project at Phase I are safe and in good performance, the leakage and deformation parameters under the design criteria.

4.1 Standardization Construction

To meet the operation challenge of unsound management system, unclear duty interface, inadequate and insufficient operation staff, standardization construction was urgently required. Against that background and to better corresponding to the local requirements, POWERCHINA cross-checked Chinese standards and general international standards as well as local standards, conducted benchmarking studies and finally established Nam Ou electricity engineering standardization system. The technical standard system, the management standard together with work standard formed the whole system. The technical standard system guided the solve of technical problems in electric power production, the management standard system standardized the operation and management process and respective function of departments, the work

standard system defined the responsibilities of each position. The standardization system assisted to manage the project scientifically and systematically, shifted the post intervention to preemptive prevention, conducive to enhancing the operation management level and core competitiveness.

4.2 Integrated Dispatching for Operation & Maintenance

With the construction of Hydropower Project at Phase II to be completed in 2020, all the seven cascades hydropower stations shall run into commercial operation, integrated dispatching shall play an important role in remarkably improve project benefits. To accommodate the flood and drought characteristic of Laos and the river basin, multi-purpose dispatching is under study for the sake of ensuring flood safety control of the river, economic operation of the cascade project, ecological friendly to the environment. Multi-temporal high-resolution precipitation forecast model built based on distributed and integrated hydrological models. Multi-purpose dispatch study carried out to maximize power generation while meeting the requirements of flood control and sediment and ecological environment protection. By availing Mass Data and cloud technology, platform is to be built for meteorological and hydrological intelligent forecast and dispatching operation of Nam Ou HPP. Adhering to the principle of "distance monitoring, real-time control, optimal operation, emergency command", Centralized Control Center is already in operation since the year 2019, which realized the dynamic remote control of hydrological information, provided basis for joint central control, optimal dispatching and economical operation of the whole river basin project.

Figure 6 Centralized Control Center

4.3 Dam Monitoring System

Dam Monitoring System, as the most effective means to comprehend the operation behavior of the dam, is of great significance for the long-term operation of the project. The Nam Ou HPP, taking account of both the temporary and long-term monitoring requirements, established a sound monitoring system covering the key parameters of deformation, stress, strain, temperature and seepage etc. Installation of the monitoring instrument and construction of the observation station were completed in synchronous with the dam filling. Hydraulic overflow settlement gauges and horizontal dis-placement gauges were installed in the dam body at different Elevation. Surface observation piers were placed on the top of dam from left to right. Monthly dam monitoring report was submitted to the chief engineer for review. External experts specializing in dam monitoring were employed under long-term contract. Regular site inspection was paid and any sign of potential safety hazard listed and closely followed up. Results of monitoring data analysis showed that the design of the Dam Monitoring System is reasonable and the working behavior of the Nam Ou HPP can be fully reflected.

For the seventh-cascade hydropower station, the dam monitoring system provided indispensible technique support for decision making on concrete panel phasing, casting time and storage time

selection. To better monitoring the panel flexibility, flexible inclinometer was introduced to cross-check with the level monitor.

With the soft rock filling rate of the sixth-cascade composite Geomembrane dam reached as high as 81%, particular attention was paid to the deformation and seepage control. Systematic monitoring on Geomembrane was made for the first time. Sona Detection and Remote Operated Vehicle were utilized underwater, which ascertained the underwater dam function well and in safe condition, consistent with the monitoring data analysis results.

5 ENVIRONMENT PROTECTION

Upholding low-carbon economy and green development, in pursuit of "building a hydropower station, protecting an environment", The Nam Ou HPP listed environment and ecological protection as priority agenda of river basin hydropower development. It attached great importance to environment protection from the beginning of the project and explored an effective environment protection system alongside project development. Targeted measures were made to ensure on-site and surrounding water, atmosphere, acoustic and ecologic conditions strictly under control and satisfactory to the local government and the public.

5.1 Regulations and Mechanism

As per the pre-examination procedure of environment impact assessment (EIA), not only explicit measures to prevent and dispose environment pollution and damage of ecosystem were stipulated, but also incorporated operation and regulation measures to ensure healthy river ecosystem after projects are in commercial operation. EIA report was submitted to local environment protection agencies for review and obtained approval. Public hearing was held and public opinions were surveyed. The feasibility report adopting seven cascades development scheme out-performed the previous high dam and large reservoir proposal, on account of its sound integration of the project with the environment and local livelihood for the lifetime service of the project. The overall layout of the construction reasonably avoided rare tree and species, and specific investment budget allowed for environment protection facilities and measures. The project complied with the higher standards of environmental protection laws and regulations of China and Laos. The environment protection awareness was enhanced, the liability was broken down to be transmitted to all the related parties and ensured strictly followed.

5.2 Impacts on Ecological Environment

Minimum discharge ecological flow, which is to prevent river dried-up and keep the stream flow continuity, was specifically and scientifically formulated for each hydropower station, Through river basin integrated dispatch, minimum discharge ecological flow was guaranteed and released all the year round, seasonal droughts and floods in the river basin regulated, downstream flood control capability improved, downstream irrigation assurance enhanced, soil erosion and deforestation reduced.

Fish and shrimp breeding zones and wildlife migration habitats protection areas were established. Various kinds of fish fry released in different seasons to alleviate the impact on aquatic and terrestrial animals and keep biodiversity of the water basin.

Figure 7 Fish Fry Release

Professional institutions were invited to carry out biomass cleaning in the reservoir area, to prevent the eutrophication of the water in the reservoir, to ensure the safety of the downstream drinking water and the health of the population.

5.3 Pollution Prevention

As potential adverse impacts lie mainly in the construction period, design optimization was made from the perspective of minimize disturbance and prevent pollutant, stringent measures were taken against pollution prevention and control. The aggregate processing system was designed to be operated within an enclosed environment to prevent rising dusts, to lower potential adverse impacts on worker health and the surrounding plants. The main access road was completely hardened, effectively reducing the dust in the construction process and ensured higher visibility thus enhancing safety assurance. The waste water generated was treated and recycled after passing through three sedimentation tanks and five drain pits to achieve zero discharge of sewage. The solid wastes were properly piled, disposed and recycled, to minimize hazards to the land and soil.

5.4 Preservation Local Culture

The first-cascade hydropower station is only 45km away from the LuangPrabang which is a world cultural heritage city. Specific landscape was designed to embrace the project function together with the esthetics and environment projection. It shall serve at tourist recreation zone after water storage of the first-cascade hydropower station.

Under the principle of "the least relocation of original residents, the least inundation of cultivated land and woodland, and the least environmental impact", the Nam Ou HPP was awarded the ecological protection prize by the Department of Natural Resources and Environment of the provincial government of Luangprabang, Laos.

5.5 Resettlement and Localization

The Nam Ou HPP covered an area of 2 provinces and 10 counties including multi-ethnic areas. Considering the opinions of the local government and the immigrants and based on the site condition, new settlement villages were carefully selected, planned and constructed. 23 new villages for immigrants were built, with over 2,300 families and a population of over 12,600. Centralized clean water supply and other necessary facilities were provided. More than 500 kilometers of roads were built or expanded, and more than 20 medium and large bridges were

built, as well as docks, schools, markets, hospitals and temples. All these have greatly improved local infrastructure and public services.

Livelihood restoration projects were orderly carried out such as providing seeds for agriculture, teaching villagers how to plant coffee. A total of more than 8,000 jobs were provided for local people. Local employees accounted for 51 percent of recruits in the Hydropower Project at Phase I and 77 percent in the Hydropower Project at Phase II. The target is to eventually reach over 70 or even 90 percent with the growth of qualified talent through technical training. In addition to recruiting for construction and operation workers, qualified locals were promoted to managerial roles as well. Local outstanding students and talents were subsidized to further professional studies in Wuhan University and Hohai University of China.

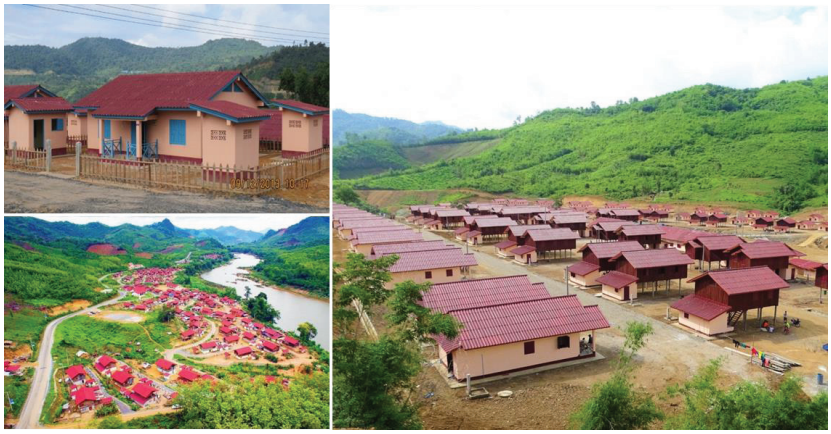

Figure 8 : New Villages for Immigration

Figure 9 : Facilities and Infrastructure Improvement

Upholding the principle of "scientific development, green development, localization, take root in Laos", POWERHINA vigorously took the initiative to align with the Lao government's national strategy, accelerated the process of localization such as integration of local culture features in the camp design. It actively promoted local administration, participated in local social welfare, provided golden autumn education sponsorship, promoted upgrading of industries, acted as a positive, enthusiastic and responsible contributor to the local economy and society. Through the above measures, POWERCHINA contributed to the sustainable development of local people's

livelihood, and was awarded for the immigration settlement relocation reward and outstanding contribution to social and economic development.

6 CONCLUSIONS

Nam Ou Cascade Hydropower Project, as the first project of POWERCHINA to obtain an overseas basin development right, echoed with Lao's strategy to become "Battery of Asia " and our wish to build community of common destiny. Guided by holistic and scientific planning that integrate social, economic and environmental objectives, through collaborative management and technology innovation, in harmony with the environment, assumed corporate social responsibility, promoted localization and culture integration, POWERCHINA overcame difficulties and obstacles, realized safe, efficient, high-quality, rapid and environmental friendly development of the project. It provided cheap and reliable electricity to Laos, enhanced stability and flexibility of the power grid, improved local economic and livelihood development, achieved sustainable development of the Nam Ou river basin. The successful development and management of Nam Ou HPP rendered POWERCHINA translating the industry chain to the value chain, turning the expertise into core competitiveness, at the same time, empowered the Laos to realize the resources advantage into economic advantage. As a pilot project under "Belt and Road Initiative", the Nam Ou HPP set a typical example for the river–basin cascade hydropower development, forged a model of China-Laos Cooperation.