SHP Technical Level in China

Hangzhou Regional Center (Asia-Pacific) for Small Hydropower

SHP seems simpler than big or medium hydro, but it is not simply a "miniature" of large hydropower technology. SHP has its own features. After decades of practice in China, rich experience in SHP technology has been gained, practiced and proven repeatedly. SHP technology has gradually matured, and its features with Chinese characteristics can be summarized as follows:

— A SHP planning system with unique features, including planning methods, standards and implementation for SHP-based rural electrification.

— Cascade development technology for SHP exploitation in combination with the harnessing of medium and small rivers.

— SHP survey and design technology and procedures with unique features.

— Diversified approaches for development according to specific sites.

— Wide application of local materials for dam construction.

— Refurbishment and renovation for aged SHP stations.

— Studying and disseminating appropriate new techniques with SHP features.

— Increasing the automation level gradually and selecting automatic standards reasonably.

In April 2003, the Chinese Ministry of Water Resources formulated and promulgated <Guidelines for the Modernization of Rural Hydro Power Technology> which pointed out the direction for further development of SHP, based on the summary of SHP exploitation in the previous decades, and taking SHP experience in foreign countries as a reference, in combination with Chinese features. Implementation of the guidelines will surely enable SHP technology in China to reach a new higher platform in the near future.

It should be noted that there are some common flaws in SHP technology in China. For example, the average annual utilization hours are comparatively low; the transmission line loss is high and the equipment is aging. All these should be improved in the future.

1. Planning approaches and standards for SHP-based rural hydro electrification

In 1982, the Central government decided to set up the first batch of 100 pilot SHP-based rural electrification counties in China, to be implemented as from 1983. Before scale-up construction, the Chinese Ministry of Water Resources chaired the preparatory work, organized a number of research institutes, universities and experienced provinces, prefectures and counties to participate in the research work for compiling the rural electrification planning. Planning is the basic work for construction. After implementation of the first batch of 100 pilot SHP-based rural electrification counties in China, the methodologies for a packaged planning, modelling system and computer software appropriate to rural electrification were developed. The characteristics of rural electrification for various types of counties were summarized, and system models for various types of rural electrification were set up.

These system models of rural electrification planning, multi-objective comprehensive assessment for projects, economic benefit evaluation, rural electrification - economy - ecosystem dynamic simulation model, prediction of energy and power demand and optimized overall balance were not only creative in methodology, but also proven with good results in practice. Much valuable experience has been absorbed in the state or ministerial standards, such as < Regulations for Compilation of Rural Electrification Planning for the SHP Areas>(1995), <Guidelines of Power Development Planning for Rural Hydropower Supply Areas>(1992), <Standards of Primary Rural Electrification in SHP Supply Areas>(1992).

Some 80,000 SHP stations have been built through large-scale SHP construction during the past 50 years or so in China. However, some unqualified SHP stations have been discarded in the past 10 or 20 years. So far, the total number of SHP stations in operation is 40,000 or so, of which 4000~5000 have installed capacity of over 500 kW each, and were properly designed and constructed. Based on these results, the Chinese government via the Ministry of Water Resources (formerly called Ministry of

Water Resources and Electric Power) stipulated and promulgated a series of SHP technical regulations and norms, fully summarizing the experience gained. Systematic and formal technical documents have been compiled, providing powerful technical support to the sustainable development of SHP and ensuring the emphasis on scientific methods, quality and efficiency during SHP construction and management. Internationally, it is not usual for the SHP industry to have so numerous and comprehensive regulations and norms. These documents are not only an important data bank of SHP development in China, but also a major contribution to worldwide SHP technical development. The Chinese government is planning to translate them into English for exchange internationally.

2. SHP developments in combination with medium and small river treatment including cascade development technology

China stresses that the exploitation of medium and small rivers is an important part of river treatment, and an inseparable part of the water resources sector. For decades, around 50,000 small and medium hydro power stations have been built at numerous rivers across the country, forming a total storage capacity of over one hundred billion m^3 and playing a key role in flood prevention, irrigation, fresh water supply and water conservation. Thousands of rivers have been primarily treated through the exploitation of small and medium rivers. That is one of the factors why SHP in China has been developed in a continual, large-scale manner, and with such speed. Concerning river harnessing, China adopts the principle of division, i.e. the central government is responsible for harnessing big rivers, whereas the local governments are mainly responsible for harnessing small and medium rivers. In the practice of SHP development in combination with treating small and medium rivers in China, a set of effective and multiple technologies has been developed, including cascade and trans-basin development.

(1) Planning for small basin cascade development

SHP cascade development is one of the important features of SHP exploitation in China. Its advantages include the full use of the hydro potential and the construction of a key SHP station at the river can regulate the flow for all the SHP stations downstream. In addition, the network based on the cascade stations can be linked to form a local grid, further increasing the economic benefit of the previous SHP in isolated operation.

Cascade development is usually implemented in one river of a county. Consideration should be given to the following:

— In accordance with the natural features of the rivers and different demands of various aspects of the local economy, efficient use should be made of natural drops. Each cascade is interrelated from a hydraulics viewpoint when implementing the cascade development. The tail water from the upper cascade goes to the fore bay or the reservoir of the lower cascade. The level of the tail water for the upper cascade is basically the upper water level for the lower cascade. Usually two indexes are used to measure the development level of the river: head utilization (the ratio between the head utilized and river drops) and the hydro energy utilization level (the ratio between the average annual power generation and theoretical potential).

— To achieve the multi-utilization objectives, each cascade has its major or minor functions. Build a reservoir at the upper reaches if possible so as to regulate the flow for the downstream stations. The run-off type stations are usually developed at a later period. Furthermore, it is beneficial to put up a daily regulating pond for the diversion type cascade station. However, a reservoir must be constructed, if it is to meet the requirements of irrigation and other purposes.

— The cascade development should be based on the benefit of the whole basin, instead of the benefit for a single station. Though it is costly to build a regulating reservoir, it would enable downstream stations to gain more benefit and so increase the overall benefit for the whole basin. Likewise, the reservoir used for comprehensive utilization may sacrifice some energy production, but other sectors could benefit. In addition, if the cost is shared among the different end-users, the unit cost could be reduced.

— In view of the shorter construction period and smaller magnitude of small basin cascade developments, all the cascades in the basin usually form a whole project, with each cascade being considered a part of the whole system. When the local economy is growing fast, comprehensive planning, continual construction and rolling development from the first cascade to the final one could be realized.

(2) Development planning for small basins

Trans-basin water diversion is widely adopted in SHP development in China especially for high head SHP stations. This is another effective mode for SHP exploitation. When the topography and geology are suitable, water from other basins is diverted to the feasible site for building the trans-basin project and this can increase energy output. According to the topographical conditions, various diversion ratios are used to compare and evaluate adjacent basin waters, which may be difficult or uneconomic to develop singly. Namely, based on the multi-year flow, set some parameters such as 0.5、0.4、0.3 m^3/（s.km^2） for economic and technical comparison in order to select the optimum diversion ratio and tunnel diameters.

An example can be taken from the Panxi stream development, originating from Dayang hilly area of Jinyun county, Zhejiang Province. The total length of Panxi stream is 30 km, the catchment area 84 km^2 and annual rainfall over 1,700 mm. The head drop from Dayang reservoir to the fifth cascade is over 610 m with a head utilization of 95%. Four measures including storing, blocking, diversion and linking were adopted at the headworks layout of Panxi project so as to make maximum use of the riverbed natural gradient and discharge, and achieve the objective of power generation first, in combination with irrigation. The main engineering includes the construction of two reservoirs with storage capacity 12.95 million m^3, 5 cascade stations and 13 units with total installed capacity of 7,565 kW. 17 tunnels were dug, with a total length of 7,435 m, open canals of total length 3,392 m were constructed; and 5 drought aqueducts with total length 210 m were built. 35 kV transmission lines with a length of 45 km were put up, and one 35 kV substation was constructed.

Panxi 1st cascade station was built behind Dayang reservoir. The reservoir is of yearly regulating type, with a capacity 11.90 million m^3. There is a clay slanting wall rock dam with a height of 45 m, length 167 m. Under the hill shoulder at the dam site, a tunnel has been constructed to divert flow for power generation with a diameter of 3 m and length of 180 m. Horizontal Francis turbines were installed with a capacity of 575 kW. Panxi 2nd cascade station is of diversion type, utilizing the tail water of the Panxi 1st cascade station plus the diversion water from an area of 1.5 km^2. There are 3 tunnels with a total length of 525 m and one open canal 1,520 m long to form a head of 220 m at the fore bay. The penstock, with a length of 480 m, supplies flow to 3 horizontal impulse turbines, which have an installed capacity of 900 kW. Panxi 3rd cascade station is of diversion type, utilizing the tail water of the Panxi 2nd cascade station plus the diversion water from an area of 6 km^2. The project traversed 2 hills, went through 3 tunnels 1,530 m in length with a 65 m aqueduct and open canal 912 m long. The forebay is connected with a tunnel, 2.5 m in diameter and 350 m long, which then connects to a 0.8 diameter penstock. The total installed capacity of the station is 2,400 kW, and is one of the key stations in the whole cascade system. Panxi 4th cascade station is of diversion type, utilizing the tail water of the Panxi 3rd cascade station plus the diversion water from an area of 20 km^2. The diversion engineering of the project is huge, including 9 tunnels 4,594 m long altogether, 2 aqueducts 5 m long, an open canal 920 m long, and the penstock diameter 1 m, accommodating 2 Francis turbines. Panxi 5th cascade station is of behind-the-dam type, 1.5 km away from the tail water of the 4th cascade station, and has a concrete stone masonry overflow arch dam, with a dam height of 25 m, catchment area 76 km^2, and storage capacity 1.05 million m^3. A tunnel was constructed at the left bank with a length of 200 m and diameter 3 m; 2 units are installed each of 320 kW.

The 5 stations have formed a SHP network, transmitting via Jinyun substation to Huzheng substation, finally connecting to Jinhua and Lishui Dispatching Centre for integration into the large grids. After the connection of SHP, the stations operated at full load during the flood period to make best use of the hydropower potential and supply energy to the large grid. During the dry period, some SHP stations supply power for peak load and some serve for phase regulation and reactive power compensation. The Dayang reservoir is of yearly regulating type and resolves the contradiction of energy shortage during the dry period.

The 5 SHP cascade stations greatly stimulated local industrial and agricultural development, and living standards of the local people improved considerably. With the adoption of a policy of “construct one, benefit from one and construct another”, funds accumulated steadily, and the technical skills developed.

3. SHP exploration, surveying and design technology and procedures

In the initial period of the 1950s, China developed its SHP with a poor technical base. In the first 10 years after the founding of the People’s Republic of China in 1949, around 9,000 SHP stations were built, with an average installed capacity of 28 kW. Most of those were shabby, isolated ones, without proper design. Since the 1960s and especially the 1970s, SHP development has thrived. A large number of SHP stations of over 500 kW were built and the technical level increased steadily.

Internationally, medium and big hydropower technology was proven in the 1960s and 1970s. However, before the opening up and reform period, it was difficult and there were restrictions for China to obtain advanced technology and equipment, including those used in the construction of big and medium hydro power, from advanced countries, so China had to learn by itself while working on the basis of self-reliance. SHP has its own features and cannot duplicate large hydropower technology. In the 1960s and 1970s, though SHP in some developed countries was advanced, it was not quite appropriate for the concrete situation in China. Therefore, SHP technology in China was actually summarized and refined through constant implementation in practice.

In the late 1970s, SHP exploitation in China was stepped up and there was an urgent need of standardization for SHP reconnaissance and design. In 1978, the Chinese government started to prepare the compilation of design norms, entrusting the Ministry of Water Resources and Electric Power with the responsibility of organizing nationwide experts for the compilation work. During several years of compilation work, in-depth research and investigation were made on SHP design, construction, operation and maintenance, and experience was summarized for the construction of SHP. In accordance with the features of SHP design, construction, operation and maintenance, and based on the actual technical and economic level, <Norms for Designing SHP Stations> was compiled and passed the appraisal made in 1984 by the Ministry of Water Resources and Electric Power. This was then approved by the State Planning Commission and was finally listed as a national standard.

The <Norms for Designing SHP Stations> states the appropriate range of installed capacity below 25 MW and unit capacity below 10 MW. The <Norms for Designing SHP Stations> stipulates the norm for each design specialty, reflecting the special features of SHP in many places. For example, concerning the requirements for hydrological data, it states, “When the duration of the run-off series at the design section is too short, it should be supplemented and extended so that the extended data cover no less than 20 years”. The problem of severe shortage of hydrological data is resolved flexibly and reliably for many SHP sites. Another example, for the design flood standards for the SHP powerhouse, it is generally taken as a one in every 30 to 50 years flood. For the checked design flood standard, it is one in every 200 years for diversion type and behind-the-dam type SHP stations; for the riverbed type SHP stations, it is 300 years. For hydrological calculation, China has stipulated the use of the ministerial standard <Norms of Hydrological Calculation for SHP Stations>. All these are rare in the global SHP sector.

So far, the SHP technical norms in China are essentially complete, covering not only the basic aspects of SHP technology, but also the specialized parts. For instance, there are <Norms for Designing SHP Automation> and <Norms of Dispatching Automation for Rural Hydropower Systems>.

In short, SHP technology in China has its own features and is also proven.

Regarding the procedures of SHP construction, China has established the following process flow:

(1) Project approval

According to the installed capacity and the investment scope of the project, the project document should be approved at different levels before construction. Generally speaking, the design work file and design documents for SHP stations with unit capacity of 500 kW and above should be approved by the provincial department of water resources. The design work file for SHP stations with unit capacity below 500 kW should be approved by the prefecture or county. The project document and its attachments should include the following:

— Project description.

— Reasons for construction and engineering features.

— Funding arrangement.

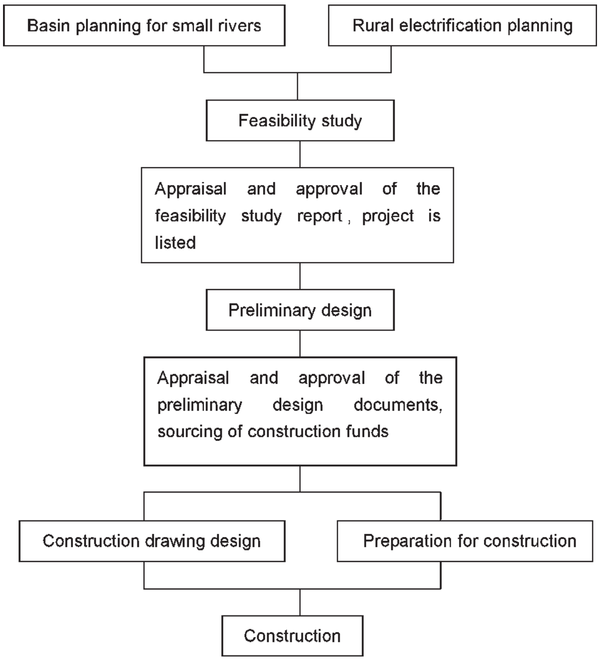
— Attachments: the planning report and hydrological and geological reports and drawings should be attached.

After the approval of the project, the owner can prepare for the start of the construction and ask the design organization to complete the design of the construction drawings. After the approval document is issued, the owner can start the construction.

The procedures for developing a SHP project are shown in the flow chart below(*next page*):

(2)Engineering construction and construction installation

The engineering construction should strictly follow the basic construction procedures and ensure the engineering quality. The projects are



not permitted to start until they are listed in the yearly plan. For the design work, it should be technically reliable and economically reasonable, safe and practical. The management methodologies including the owner's responsibility system, equity system, engineering supervision system and shareholding system for exploiting SHP stations, which have been introduced for hydropower development in recent years, all stress the management of SHP construction projects.

Generally, SHP stations of tens to a few hundred kW installed capacity are constructed by the county, township or village, and the county bureau of water resources provides working guidance support by sending technical staff and sometimes helping to order the equipment. SHP stations of a few thousand kW are generally constructed by the organizations at the province or prefecture level. In the early period, SHP stations were constructed using physical labour or manually operated machines. Equipment such as bulldozers, tractors, dredgers, rollers, lorries, and concrete mixers are sometimes used for some bigger SHP projects or where there are higher dams. Projects at the provincial and municipal levels have a higher level of mechanization. Electromechanical installation is usually completed by special installation groups at the county level, or completed by the villagers themselves under the guidance of some technical personnel. The SHP construction period is normally 2~3 years, though some SHP projects are completed within one year.

4. Various flexible modes of exploitation based on actual site conditions

China is vast in area, and the hydropower potential is abundant and scattered. After decades of implementation, various site-specific and flexible modes of SHP development with diversified designs have been created, forming a kind of huge museum of living SHP. Nearly all types of SHP stations listed in the textbooks can be found in China.

— *Design head of SHP stations:* from 12 m to 1,074 m.

— *Turbine types*: axial, Kaplan, tubular, bulb type, Francis, impulse, Turgo, cross flow, reversible pumped storage units and micro packaged units.

— *Dam types*: All dam types exist, including earth dam, stone masonry dam, concrete dam, rock-fill dam, concrete face rock-fill dam, rock core wall dam, roller compact concrete dam and rubber dam. The longest dam is 5,842 m.

— *Diversion system*: including open canal, aqueduct (the longest is 2,000 m long, 27 m high, with a flow rate of 1.7 m^3/s), various pipes with or without pressure, tunnels (the longest is 4,000 m, with a diameter bigger than 10 m).

— *Penstocks*: various, in the 1980s, pre-stressed concrete penstocks were widely adopted; the maximum head is 200 m, the maximum diameter 3.2 m.

— *Powerhouse*: including above ground, underground, circular and oval.

— *General layout*: including diversion type, behind the dam type, mixed type and riverbed type.

— *Station elevation*: The highest is one built in Tibet with an elevation of 4,700 m.

The rich and extensive experience with flexible and diversified modes of SHP development make it possible for China not only to continue to exploit SHP resources in various parts of the country, but also to share its experience with the world community and to provide technical services to developing countries, thereby contributing to the promotion of the global SHP profession and raising its level of technology.

5. Local materials widely adopted for dam construction

In this respect, China has accumulated lots of experience. Almost 80,000 earth-filled dams of various kinds with a height less than 30 m have been built, as well as over 500 stone masonry arch dams with a height of more than 20 m. Others include the stone masonry gravity dam, the masonry hard shell dam, dry-lining masonry dam and various kinds of earth and rock dam. These practical and proven technologies provide important technical support for extensively adopting local materials and local labour, thereby speeding up the pace of SHP development. During recent years, the dam types most commonly adopted include:

(1) Stone masonry arch dam

As long as the topographical and geological conditions allow (L/H=3.5), and especially for those SHP projects with a dam height less than 50 m, the stone masonry arch dam is the first choice for dam type. Compared with the stone masonry gravity dam of the same scale, it can reduce the construction volume by 1/2 to1/3. During the design stage, it is usually compared technically and economically with other possible dam types. The body shape of a stone masonry arch dam is the same as that of a concrete arch dam. For small-scale stone masonry arch dams, single or double radius dam types are adopted, and for higher stone masonry arch dams, double curved parabola-type arch dams are used.

(2) Small-scale stone masonry multi-arch dam with buttresses

This type of dam is mainly composed of arch cover plates and buttresses, and can be adopted when the river valley is relatively wide, the dam is not so high, and the foundations of both sides of the riverbed and dam are fairly good. This kind of dam can save 30~50% in construction volume compared with the stone masonry gravity dam of the same scale. Water can flow freely over the dam crest, and since the dam top is curved, the overflow length is longer than for a straight-line shape.

(3) Arch dam

When the dam height is over 40 m, the concrete arch dam is a must for selection and comparison during engineering design, so long as topographical and geological conditions permit. At present, when designing a dam body with a height over 40 m, the concrete arch dam is one of the most frequently used dam types. The multiple curve types of arch dams are made up of circular, parabolic or elliptical curves, and can fully utilize the load bearing capacity of the dam body to reduce the amount of construction required for the dam.

(4) Rubber dam

Rubber dams, which can increase or decrease their height easily, are generally used on the riverbeds of hilly areas, plains or spillways. During the dry season the rubber dam bag will be filled with water (air) so as to retain the river flow, and the water (air) is discharged to decrease the dam height in the flood season to release floodwater and so prevent the upper reaches from being flooded. Rubber dams are usually adopted in those areas with a low head and large flows, or at spillways to increase the water head, and improve the flow-regulating coefficient and the flow utilization ratio, thereby raising the power-supply reliability. The rubber dam consists of a rubber bag, a concrete foundation, and a water- (air-) filling and water- (air-) discharging systems. The rubber bag is made of canvas and chloroprene rubber, or several layers of acrylic acid fibre canvas and rubber compressed under high temperature, then anchored to the dam foundation and side walls, so as to form a dam after water (air) filling. Compared with a movable gate of the same size, the cost of a rubber dam could be 30%~70% lower. Furthermore, the rubber dam is easy to instal on a spillway without gate and the structure is simple. It can improve regulating capability, thus increasing reservoir capacity with consequent benefits.

6. Equipment and technical renovation of old hydropower stations

At present in China there are installed units with about 1,536 MW capacity which have been in operation for more than 30 years, 6,925 MW in operation for more than 20 years, and up to 13,853 MW that has been in operation for more than 10 years. These early operated units are generally poor in their performance and efficiencies, and lots of units are in unstable operation, with insufficient output achieved, or where cavitation easily occurs, and many fail to run under optimum working conditions for a very long period. In addition, the water quality of some rivers is very poor with a heavy silt content, which would destroy the turbine runner within one year after operation, or would give a very low efficiency in operation. For other hydropower stations, the initially selected units are possibly unsuitable for use or uneconomical now because the hydrological conditions have changed a lot. Additionally, although some units are in operation under normal conditions, a long running period has caused their performance to deteriorate. After an overall quality investigation, the above-mentioned different problems have been classified and summarized, and it is concluded that there are units with an installed capacity of 8,000 MW in total suffering from the above issues. In order to improve operational security and economic benefits, these hydropower stations should be technically refurbished. This renovation can save investment and achieve profits fast. Generally speaking, the cost of replacing a runner can be recouped within one year, and the generation can be increased to a certain extent. If all the SHP stations affiliated to the Ministry of Water Resources increased their output by 5% after technical renovation, it would be equivalent to building a hydropower station of 1300 MW, which could produce very huge profits. At present, some professional administrative authorities have already published a lot of standards or norms, in which recommendations on the steady operation range and efficiency-guarantee values of different hydro turbines have been given, and product quality has been classified based on test results. It is generally acknowledged that the overall efficiency of units with different capacities should not be lower than the values shown in Table 1.

Table 1 Requirements on the overall efficiency of a unit

Unit capacity（kW）	The overall efficiency of a unit should not be lower than
＜100	68%
100~500	72%
500~3,000	78%
＞3,000	83%

In order to improve the overall efficiency of SHP stations, much attention should be paid to upgrading the electro-mechanical equipment, so as to save investment and achieve profitability faster. The following three means are usually adopted:

(1) Make small repairs or changes to the original conditions

For example, for rough machined runner blades, a model should be prepared, and according to the requirements of this model, the blade surface should be polished. To reduce the wastage rate during runner processing, the water discharge side is often thickened, but this leads to a relatively high velocity of water flow here, resulting in high hydraulic losses. After the blade discharge side is polished thinner, the flow discharge capability is improved, and the output also increased. The efficiency of some hydropower stations can be raised by 1%~2% after blade modification, and vibration under low load operation is also reduced.

It is also feasible to cut the blade. Generally, the water-intake side is cut away so as to reduce the radius and its angle. If the water-discharge side is cut away, the discharge angle of the blade and its open gauge is increased, and the optimum unit flow will also be increased. Then the optimum unit speed will change slightly too, and of course the efficiency would then be improved. For other hydropower stations, the space between runner blades is too small, and the required output value cannot be reached, so according to the results of model tests, part of the water-intake side and the discharge side should be cut away at site. The thickness of back of the runner is reduced, therefore reaching the required open gauge and increasing the unit output by 5% or so. However, this may influence cavitation and other operational characteristics.

(2) Change the main components

For those units with poor machining quality and hence operational performance or those severely damaged after operation, the old damaged components should be replaced with new ones, and generally the key parts of units should be changed. If a stainless steel runner is adopted to replace a damaged carbon steel runner, the life span of the new runner can be extended to 10~12 years from the original 2~3 years. As for those hydropower stations on rivers with high silt content, the labyrinth seal rings of the units are always abraded, and the clearance between the guide vanes increases. In this case, many more parts need to be replaced. The runner characteristics of propeller turbine units are related to the setting angle of the blades, and the small-scale unit generally adopts a large-angle propeller runner, so as to achieve higher efficiency and better cavitation characteristics over a large range of flows. This point has been considered for the runner blades at some hydropower stations, and compared with the old runner, the output can be increased by 1%~2%.

(3) Remove the old and rebuild

For units, which have seriously aged after a long period of operation, the rehabilitation expenses are very high, and neither economical nor safe, so in this case, one should consider rebuilding. In addition, if the hydrological conditions change, it would be better to rebuild, even if the unit is in normal operation or can operate over a very long period. During rebuilding, most parts of the unit have to be removed, and only the pit remains. Rebuilding is time consuming, and is generally carried out in the dry season. It often costs much, and will cause a loss in power generation. On the other hand, the unit can be reselected or redesigned, so that some advanced technologies can be adopted to get back the investment in a short term, so the benefits arising from rebuilding are also very evident.

7. Studying and popularizing applicable SHP new technology

After decades of development, the SHP industry has already developed a complete technical system covering surveying of resources, planning, design, engineering construction, equipment manufacturing, and operation and management. However, in all these fields there still exist many technical issues that need to be studied in-depth. Major technical breakthroughs and wide application of technical achievements will reduce SHP costs, improve its market competitiveness, and promote the swift development of the SHP industry, ultimately producing enormous social and economic benefit.

(1) The main scientific and technological results from SHP R&D

— Design optimization, rational planning of water systems, water collecting network and trans-basin water diversion.

— New types of hydraulic structures and building materials such as rolling concrete technology for dam construction, siphon intake technology for hydropower stations, and the application of rubber dam, glass steel tube and other new materials.

— Developing and popularizing new electro-mechanical equipment, such as the type series of small-scale turbine-generator sets, pressure regulating valves, the new-type operating device of hydro turbines, the electronic load controller, the automatic control technology of SHP units, and anti-cavitation and abrasion-resisting technologies for small-scale hydro turbines.

— Technical rehabilitation of SHP stations.

— Developing small-scale pumped storage power plants.

— Optimization of operation of SHP stations.

— Automatic dispatching technologies for the local grids of SHP.

(2) Application of new electro-mechanical technologies

At present, the new technologies of SHP electro-mechanical equipment mainly include:

— Gravity butterfly valve. In the past the inlet valve of an SHP unit would be mainly an electrical and manual butterfly valve, ball valve or gate valve. When the unit broke down, the valve usually failed to close automatically since the plant-service power was not reliable. In order to overcome this shortcoming, the gravity butterfly valve and ball valve have been developed in recent years, which can close automatically due to gravity. Its closing time is adjustable, and the closing action is reliable. Furthermore, the valve can close section by section, to prevent the water-diversion system from suffering too high a pressure, and at the same time, it can also close quickly to prevent runaway of the turbine.

— Air-vent valve. At a hydropower station, when *LV/H* of the long pressure diversion tunnel is greater than 15~30, generally a surge tank needs to be erected, but the surge tank requires a large amount of civil engineering works, a long construction period and suitable topographical conditions. For SHP, the air-vent valve is adopted to replace the surge tank, which can save on investment and shorten the construction period. The function of the air-vent valve is to open quickly when a turbine unit sheds its load and the guide vanes swiftly close. The flow which would have passed through the unit is thus discharged through the valve. After the unit closes, the valve will close slowly, so that the flow inside the diversion system can vary slowly and prevent the pressure rising in the diversion system and the unit from reaching runaway speed.

— Speed increase device. After adopting a speed increaser in the rehabilitation of aged stations, there will obviously be an increase of energy loss of possibly less than 0.5%~1%, but with the adoption of a high-speed generator, the expenses of the station can be remarkably reduced, and the unit’s efficiency improved. The service life of a speed increaser is about 100,000 hours to several 100,000 hours generally, and can run reliably for a long time, and bring more economic benefits to stations. Through the use of a speed increaser, a low-head power station can change its transmission ratio, thus making the hydro turbine run at its optimum working condition with high efficiency, and also can improve the design of the powerhouse layout.

— The guide vane control mechanism. For small turbine units used for base load in a power grid, an expensive governor with a complicated structure can be omitted because frequency regulation is not required. It can be replaced instead with an electrical and manual spring type energy-storing device or a hydraulic actuator with low cost for its operation and maintenance. When the operating power source of a unit is cut off, the spring energy-storing device automatically closes the turbine, and it can also achieve this in stages.

— The automatic control system. The automatic control, regulation and protection system of a unit has developed because of the popularization of computers. The system can realize automatic shutdown, with high reliability, low workload for design, maintenance and installation, and only occupies a small space, so this is an ideal device for achieving unmanned control or fewer operators on duty for SHP units. It consists mainly of 2 operating modes, one is single unit operation, and the other is in connection with the power grid. In single unit operation, the unit can be automatically synchronized to connect to the power grid, and operate with the variation of forebay water level, according to given frequency and voltage settings, and meanwhile, the unit can achieve protection functions in case of over current, over voltage, over load, low voltage, overrun, low frequency, cut-off of technical water supply, and excessive rise in bearing temperature.

— SCADA system of local power grid. With the development of SHP, SHP stations are sequentially incorporated into power grids, so as to form rural power grids made up of SHP stations and users. Rural power grids need a reliable real-time dispatching and administrative centre, and the automatic dispatching system based on computer supervision and control is the technical way to achieve this result. In terms of hardware, the automatic dispatching system can be divided into the main station (MS), the communication and transmission equipment, and the remote terminal unit (RTU). Owing to the rapid development of information technology, lots of functions of this system are incorporated into the computer through chips, giving rise to even more advanced and reliable new products.

— MODULAR substation. The MODULAR substation is mainly located outdoors, and the primary electrical equipment adopts small-scale switching equipment with high performance, and energy-conserving transformers. The secondary equipment adopts a microcomputer-based control and protection module with a high dependability. Site installation, commissioning and maintenance are simple and convenient. So the outdoor miniaturized MODULAR substation will be the trend for future development.

— Hydraulic metal structures, such as the chain-type trash cleaner, the automatic hydraulic cleaner, the automatic water-level control gate, and the hydraulic control gate. With the adoption of the automatic cleaner, the cost for operation and maintenance can be reduced, and the operating dependability of the station improved. It does not cost much, and so is worth popularizing. For the head loss at a hydropower station, it is usual to have a difference of 20~30 cm in water level at the trash rack. However, for a hydropower station with low head, it is very difficult to raise the efficiency by 2%~3%. Therefore, the adoption of an automatic cleaner should be an important measure to achieve safe and high-efficiency operation at low-head hydropower stations.

The gradual popularization of the above-mentioned new technologies will create new know-how in the SHP profession, with advanced parameters, rational price, reliable operation and convenient maintenance. In addition, since the electro-mechanical products are improved and upgraded very rapidly, these technologies are constantly upgraded, and will continuously promote the further development of SHP in China.

8. Gradually improving the automation capability and rationally selecting the automation standard

In April 2003, the “Instructions on the Technical Modernization of Rural Hydro” was issued by the Ministry of Water Resources, which clarified the technical direction for the development of the rural hydropower sector in the years to come, in order to quicken the pace of modernization for China’s rural hydropower. The document pointed out the direction for standardizing and guiding the rural hydropower sector for technical advancement. The overall objectives are, prior to year 2010, 50% of rural hydropower plants and their power grids should be modernized, and in 2015 the rural hydropower sector should be all modernized. Through scientific and technical innovation and management improvement, the competitiveness of the rural hydropower market should be noticeably improved. ■

An Electric Device for Cleaning up Trash Rack

—Manufacturing Experiment at Ancheng Hydropower Station

1 General description

Ancheng station, a cascade one at the lower reach of Fushi reservoir in Anji county, Zhejiang province, has a diversion channel of 43km, with the main section extending 25km and the normal diverted flow of 11.5m^3/s. Passing through villages, fields and mountainsides, the channel carries lots of trash, branches or leaves. This station is located at the end of the main section of the diversion channel, with 2 siphon-type turbine-generator sets of 1000kW each installed, and the design water head is 28m and the unit discharge 4.25m^3/s. At the intake of penstock, it's very difficult for operators to remove the trash manually at the forebay due to the limited width of trash rack and the fast speed, which principally restricts the output of unit. If removing trash during operation, the open gage of guide vane commonly needs to be reduced. Therefore, replacing manual operation with a set of mechanical device for trash removal is highly expected.

2 Design principle

1) To set the built-in grooved track under concrete at each side of the forebay intake, which enables a chain-belt to move in the groove with "its inside up and the outside down". The grooved track fixes the chain belt and bears side pressure from the chain-belt as well.

2) The chain belt is driven by two upper driving gear-panels, and synchronously positioned by the lower passive gear-panel, to ensure the chain belts at both sides to move in a synchronous rate.

3) Driven by the shaft pins (or the chain boards) of two chain belts at the same level, a special comb-scraper moves to scrape off all the trash clinging to rack surface or filled in screen rack, and finally trash is delivered to the forebay ground. The structure and principle of this electric device called "electric trash dredger" are shown in Fig. 1.

3 Technical requirement

1) After removing the original vertical trash rack in a single-board structure, a new one, extending from bottom to top of the forebay in an oblique angle of 76°, is to be set up. It requires straightness and evenness of screen racks; equal spacing of screen racks; and an extra smoothness at the joint of two trash racks, so as to ensure the effective operation of the scraper.

2) Adopting a chain-belt driving structure, the running speed is designed as slow as possible for an easy observation and control, and meanwhile, the interference and resistance of the scrapper under water can be reduced as well as the abrasion. Therefore, a gearshift with large specific speed and a low-speed asynchronous motor are selected as the power sources.

3) The length of the chain board should be appropriate. If too long, it will cause a large size of the fluted disc; however if too short, the number of chain boards has to be increased, and the fixing mode of the scraper and the position for power

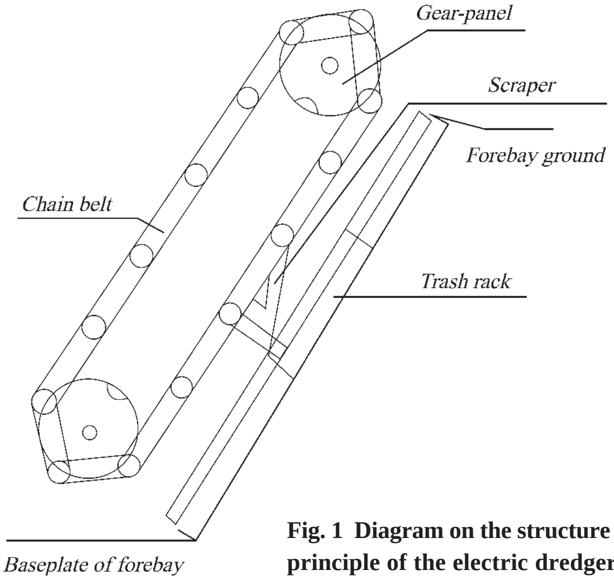


Fig. 1 Diagram on the structure and principle of the electric dredger

transfer of chain belt have to be changed.

4) Moving in the grooved track, the friction on the chain belt should be restricted to its minimum. In particular, the resistance of water flow and trash on the scrapper can be transferred to the grooved track through shaft pins. Therefore, in terms of the up-and-down movement of the chain belt in the grooved track, a rolling structure should be adopted to avoid direct friction between the chain belt and the grooved track.

5) The scraper can automatically stop at a certain place when reaching the forebay, so that trash can be removed from the scraper to prepare for the next effective operation.

4 Manufacturing process

1) The trash rack is one of the key parts of an electric dredger, and as per the design and technical requirements, it should be welded and made locally with steels self purchased.

2) The processing & installing quality of the chain belt is also a key issue for an effecient electric dredger. The chain boards, the shaft pin and the steel-pipe case shall be assembled after processing, and the chain cannot be fixed to the shaft pin too tightly. The abrasion of the shaft pin can be much reduced because of low speed and infrequent operation. The steel-pipe case of shaft pin rolling along the steel rod enables the chain board not to be in direct contact with the groove steel, and changes rolling or sliding between the shaft pin and the steel rod to be a contact of point-and-line, which thus greatly reduces the friction of the chain's operation. The structure of the chain belt and the grooved track are shown as Fig. 2.

3) The processing of grooved track: ① it aims to fix the running range of the chain. Welding a steel rod at each side edge of the grooved track plays two roles: the first is to make the chain move with its half part in the grooved track, and to restrict and position the operation of the chain; the second is to transfer the chain force to the steel rod and the steel part of the grooved track through the shaft pin. ② the grooved track is set in parallel with the plug-in groove of the trash rack at single side. When pre-embedding the grooved track, the space between upside and downside, left side and right side shall be equal at both sides of the intake, so as to ensure a stable up-and-down move with no left-to-right or front-to-back swing, and therefore, the electric dredger can works effectively.

4) The processing of scraper: thick steel plates are used for two side-panels, in the middle of which 2 grooved steel rods are welded side by side. At the side near the trash rack, the racks of same spacing are to be welded in the grooved steel rod, together with those of trash rack, which forms a comb-scraper for dredging trash or weed. The structure is shown as Fig. 3.

5) The gear panels and the shaft in top and bottom are to be processed locally according to technical requirements; the thick steel-plate is used for gear panels and the centerline spacing of the gear mouth is based on the hole length of the shaft pin; in order to facilitate installation or dismantlement, the lower shaft is divided into two equal parts, which are joined by a steel pipe case and fixed by pins.

5 Installation and operation

1) After pre-embedding the grooved track, the upper and lower bearing pedestals shall be installed and fixed, as well as the upper & lower shafts, and the gear panels; after the gearshift and the electromotor fixed, the chain shall be installed, and the

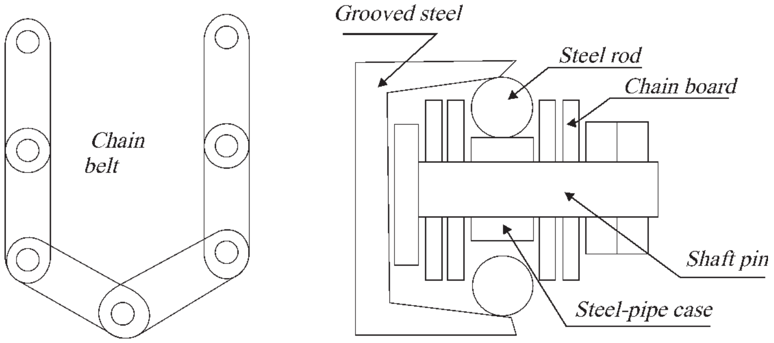


Fig. 2 The structure of the chain belt and the grooved track

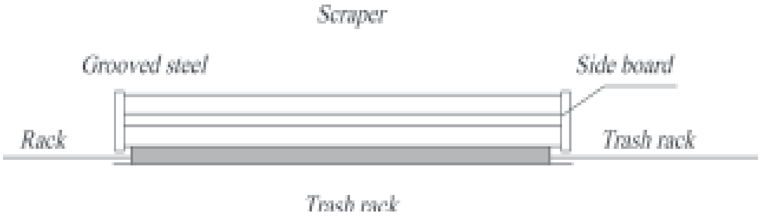


Fig. 3 The comb-scrapper for cleaning up trash rack

height of the upper shaft should be adjusted carefully to ensure a reasonable space for chain belts at two sides.

2) Switching on power and having a no-load commissioning, to observe the operation or counterwork of the chain belt in the grooved track. To deal with any problem and make technical improvement.

3) To install the scraper based on the normal operation of the chain belt system. To check and make sure that there's no colliding or counterwork between the racks of scraper and those of trash rack.

4) To have no-water trial, and after normal operation, further commissioning with water shall be made and finally operate with load for generating electricity.

6 Existing problems and measures taken for improvement

With a certain period of operation and coordination, the mechanical noise of the electric dredge goes down gradually. If using ordinary steels for the chain, the service life will be shortened and more maintenance needed because of rusting. Therefore, if possible, it's better to use stainless steel, which will deal with the rusting issue in spite of an extra nonrecurring cost. In addition, it is expected to design and install a kind of circulating structure on the forebay ground, which can take the trash or weed from the scraper and convey onto the rubber belt for deliverng directly to the trash lot. It aims to automatically complete the whole process of cleaning up trash rack by pressing only one function key.

According to the actual situations, the “circulating electric dredger with comb scraper and chain belt” is designed relying on local technical resources, and manufactured and installed successfully on-site with special purchased materials and locally prefabricated parts. Based on over one year's operation, this device is proven to be of high working efficiency, low power consumption, reliable running, simple structure, convenient maintenance, easy processing and low cost, which would have a prosperous prospect for being popularized and applied in other similar hydropower stations. ■

(Written by Shen Xuequn)

Letter from HRC

Dear participants of TCDC workshops,

In the auspicious Chinese Year of Rooster, we would like to extend you and your family our heartfelt wishes for happiness and prosperity.

Entrusted by the Ministry of Commerce of P. R. China, by now HRC (Hangzhou Regional Center for Small Hydro Power) has already hosted 38 TCDC international training workshops on SHP, and nearly 700 international engineers or technicians from around 70 countries participated. It is believed your stay in China offered you valuable experience through the classroom presentation, discussions, study tours and various contacts with the local friendly Chinese people. It is meanwhile expected that we could continuously carry out all-round exchange and cooperation in the field mutually concerned.

Thereby, HRC’s homepage ***(www.hrcshp.org)*** was set up years ago for dissemination of SHP information, and it has already been browsed by hundreds of thousands of SHP professionals for it is informative, applicable and rewarding. Now a new column called ***“HRC Alumni”*** is open especially for the participants of TCDC SHP training workshops, inside which the personal details of each former TCDC participant will be online, and participants can also log-in for raising any comments or suggestions, as well as get acquainted with other friends for exchanging experience and technology to consolidate friendship and SHP cooperation. In such a way, all of us can work closely with each other, regardless of the geographical distance, and share valuable information and further strengthen cooperation among us. You, as our friends, are expected to timely provide us the SHP-related information in your countries (such as policies & regulations, project cooperation, project bidding, international meetings, training and etc.) by means of giving introductions, reports, brief news, business opportunities or with vivid pictures. We will put the relevant information on HRC’s homepage, and possibly select some to distribute internationally through our periodical ***“SHP NEWS”***.

Besides, should there be any change of your personal contact details or other information concerned, never hesitate to contact us directly, since HRC, as the family of global SHP, is the home for all of you.

Thank you for your attention. Looking forward to hearing from you.

Yours faithfully

Dr. Chen Shengshui, Director of HRC

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Conference Held for Discussing Ecological Impact of Water Project

On August 1st, a forum titled ***Ecological Impact of Water Projects*** was opened in Beijing. Centering on the theme of "***attaching importance to ecological environment protection, and making water projects beneficial to mankind***", experts and scholars from different fields, people of various circles, who keep an open eye on the undertaking of water resources, debated on water resources management and its relation with ecological environment, and make suggestion to the construction of water projects and improvement of ecological environment. Over 300 people of various circles and MWR staff attended the forum.

Minister of the Ministry of water Resources (MWR), Mr. Wang Shucheng, attended the forum and gave a keynote speech. Vice Minister of MWR, Mr. Suo Lisheng delivered a theme speech and presided the forum in the afternoon. Vice Ministers Mr. E Jingping, Mr. Liu Guanghe, Ms Zhou Ying and Chief Engineer of MWR Mr. Liu Ning also attended the forum. The attendees probed into the ecological impact of water conservancy projects from theoretical and practical aspects. Former Minister of MWR, Jing Zhengshu, announced the rating results of proceedings presented in the forum and awarded 32 winners. The article– "***Ecological Environmental Protection and Solution of SHP Development***" presented by HRC was in the winner list.

Minister Wang Shucheng pointed out in his address that, promoting benefit and abolishing harm of water is always a major undertaking in China. Water projects have played an irreplaceable role in economic and social development of China for thousands of years. The development of water projects should not sacrifice or at the cost of destroying ecological environment. It is our duty to protect ecological environment. Water professionals should pay more attention to ecological and environmental problems, and should shoulder the double responsibilities of water construction and ecological protection. On behalf of MWR, Minister Wang Shucheng also welcomed people of various circles stick to scientific development view, and make valuable suggestions on how to deal with ecological impact of water projects from different aspects, and encourage the whole society participate and support a harmonious development of water projects with ecological environment. ■

A Chinese Magazine "Small Hydropower" by HRC

The Chinese "Small Hydropower", a magazine that National Research Institute for Rural Electrification (NRIRE) and Hangzhou Regional Centre (Asia-Pacific) for Small Hydro Power has edited and published for 124 issues (bimonthly), was allocated with the International Standard Serial Number ISSN 1007-7642, and China Standard Serial Number CN33-1204/TV. It was published in Chinese attached with title of articles in English. Its special features are technical experience of SHP development in China. Information of international SHP activities and important events in the field of SHP have also been widely included.

This magazine carries news, views and articles on all aspects of small hydro power. It is useful to those who are intersted in technical experience of SHP development in China.

"Small Hydropower" is the only professional publication on small hydropower in China, which is issued domestically and abroad. It is widely circled in all corners of China concerning SHP, and getting more and more popular in over 600 rural counties which is primarily hydro-electrified, more than 2,300 counties with hydropower resources, more than 50,000 small-sized hydropower stations, thousands of colleges or universities, research institutes and other administrative authorities on SHP. Advertising is welcome for any equipment manufacturer to target Chinese market on SHP construction, equipment purchasing or other businesses. ■

Environmental Issues and Management for Hydropower Peaking Operations

Helen Locher: Hydro Tasmania, 4 Elizabeth St, Hobart, Tasmania, Australia, helen.locher@hydro.com.au

Abstract: *Many hydropower plants are operated as peak generators or frequency controllers, because they can change their output quickly to follow the fluctuating power demand. When meeting peak load requirements, a power station is turned on at a particular time during the day, generates power at a constant load for a certain number of hours, and is then turned off or set to a different load for another time period, resulting in a high variability in flow discharges. Where reservoir hydro schemes are operated primarily to provide peak load services, there are particular environmental risks that should be considered in any environmental impact assessment. At a minimum these should focus on water quality, fluvial geomorphology, riparian vegetation, macro-invertebrate and fish communities underpinned by a sound hydrological analysis. Frequent temperature changes may occur downstream of a peaking power station; increased seepage-induced erosion of riverbanks due to frequent water level drawdowns; and impacts to macro-invertebrate and fish communities due to rapid and frequent in channel habitat conditions. With a sound understanding of the potential environmental issues, there are strategies that can be employed at the siting and design stage to minimize or mitigate these risks, including but not limited to minimum environmental flows, ramping rules, utilization of a re-regulation storage and localized treatment works.*

Keywords: *hydropower, environmental, peaking, hydropeaking, mitigation*

1 Hydropower peaking operations

Hydropower schemes are built on many scales, involve different project types, and play different roles in an integrated energy system. Operating patterns vary, and discharge patterns to the downstream river environment reflect whether the station is operating in base load, peak load or frequency mode.

When meeting base load requirements, a power station usually discharges a constant flow all day and can maintain this for days, weeks and even months depending on the scale of the scheme and the generation needs. When meeting peak load requirements, a power station is turned on at a particular time during the day, generates power at a constant load for a certain number of hours, and is then turned off or set to a different load for another time period, resulting in a high variability in flow discharges. Hydropower stations may also operate in frequency mode, where generators are brought on or off depending on the changing electricity demand throughout the day, essentially ‘following’ the load.

Many hydropower plants are operated as peak generators or frequency controllers, because they can change their output quickly to follow the fluctuating power demand. A hydropower generating unit can start up or stop within tens of seconds, which provides an important role in an integrated energy system where each type of energy source can be used to its best advantages. Because of its flexibility in generating patterns, hydropower can optimize the efficiency of less flexible fossil of nuclear generation options, and also offers a backup for other more intermittent renewable energy sources such as wind and solar.

Reservoir hydro schemes in particular provide considerable flexibility in energy provision, because with their larger storage they can be operated to provide either base load or peak load services. Run-of-river hydropower schemes provide base load options, but with less flexibility in their ability to provide peak power because of their smaller storage capacities. Pumped-storage plants are particularly well suited to meeting the peaks in electricity demand; they essentially work as a huge storage battery by charging or discharging power according to the system’s demand.

2 Potential environmental issues with hydropeaking

Where reservoir hydro schemes are operated primarily to provide peak load services, there are particular environmental risks that should be considered in any environmental impact assessment. With a sound understanding of the potential environmental issues, there are strategies that can be employed at the siting and design stage to minimize or mitigate these risks.

With any hydro scheme, the downstream river environment has an altered hydrograph due to the curtailing of major floods and a flow range restricted to the turbine discharge capacity. For a peaking station, a typical hydrograph shows twice-daily fluctuations from off to full capacity discharges often with weekend shutdowns. A peaking station may show consistent daily to weekly patterns of discharge throughout the year rather than the strong seasonal pattern that might be shown for base load providers, and depending on the scale of the scheme inter-annual variability may be low.

Downstream effects on water quality depend on the storage configuration and offtake depth. If the storage is deep and stratifies and the offtake is low, the downstream environment may experience frequent temperature and dissolved oxygen fluctuations particularly during the summer period, with the power station injecting cold water from deep in the reservoir into the warmer waters of the receiving environment. In situations where there are downstream pollution sources draining into the river system, peaking power station discharges can cause pulses of polluted water downstream rather than a general dilution effect when operating to meet baseload demand.

Downstream effects on the fluvial geomorphology and dominant geomorphic processes differ if a power station is operating to meet base versus peak demand. Major issues with any hydro operations are with the reduced sediment supply to the downstream environment and the erosive capabilities of continuous larger than natural baseflows for baseload operations. With peaking operations, the significant flow discharge patterns affecting the channel form are the rate and frequency of water level rise, the time the station is at its maximum discharge level, and the rate and frequency of water level drop. A rapid increase in water level has considerable bank scouring capabilities. The amount of time the power station discharges at its full capacity influences the degree of saturation of the river banks, which in turn influences the degree of seepage-induced erosion that may occur when the power station turns off. Frequent and rapid drawdowns in water level result in considerable pore water pressures as the water drains out of the banks, so with peaking operations the frequency of seepage-induced erosion events increases, however the severity of any one event may be less than otherwise if the power station has not been on long because the banks will not be as saturated.

Downstream effects on riparian vegetation with any hydro operations can be a loss of species cover and diversity in the riparian zone due to waterlogging and inundation, lack of regeneration and recruitment, and habitat alteration due to bank erosion. Inundation is the submergence of vegetation that prevents gas exchange, and prevents plants carrying out photosynthesis and respiration through their leaves. Waterlogging is the submergence of the root zone, which causes depletion of oxygen in the soil and prevents respiration by plant roots. Light limitation is also a stress because plants require adequate daylight hours without inundation or waterlogging to acquire carbon through photosynthesis. With peaking operations there are reduced risks of impact due to waterlogging and inundation, as the riparian zone is drained and exposed to sunlight on a daily basis. However there is still the case of limited regeneration and recruitment, because seedlings can not establish on the banks where water levels rise rapidly several times per day and wash them away. Banks close to the power station may eventually end up with a high percentage cover of mineral substrates, and riparian tall woody shrub species may be replaced with ephemerals such as grasses, gramonoids (grass-like plants) and tolerant semiaquatic herb which may provide some structural stability to river banks.

Downstream effects on macroinvertebrates (e.g. aquatic insects and micro-crustaceans) for any hydro operations are often a reduction in species diversity and abundance, as well as loss of edge and snag habitat. The significant drivers of these impacts are that the water levels with the power station off are often lower than mean summer baseflows resulting in less habitat availability for colonization, and water levels with the power station on are often higher than mean winter baseflows resulting in greater depths and current velocities than optimal for some species. With peaking operations, water levels change across this range several times per day, and frequent water level as well as temperature changes would cause high stresses on the instream biota. For example, high shear stresses, that is the force applied to the river bed from rapidly rising water levels, is associated with faunal displacement and possibly bed movement under rapidly varying flows.

Hydropower schemes can affect migratory aquatic species due to the physical barrier to upstream migration presented by the dam itself. Baseload discharge patterns can reduce fish population in the downstream environment due to reduced macroinvertebrate food supplies, loss of snag habitat, and impacts on spawning and migration cues due to changes in the seasonality of flows (and in cases temperature). Where there are natural downstream obstacles to fish migration such as river gorges, baseload discharge patterns may cause fish migration difficulties due to sustained high flow releases, whereas peaking discharge patterns may provide more frequent opportunities for migration through these gorges.

Social issues can also arise due to peaking operations, for example human safety issues with rapidly changing water levels, risks of stock stranding, and issues with pump setups for landowners.

3 Investigating environmental impacts due to hydropeaking

Investigations of environmental impacts of hydropeaking operations must be underpinned by a sound analysis of operating patterns and downstream hydrology. The drivers of impact in the downstream environment are the rapid changes in flow, and at any given point in the system this will result in different water heights, current velocities, degree of backwater inundation or channel dewatering, ramp-up and drawdown rates. A detailed set of gauging sites and water level recorders will provide basic data that can then be fed into a hydrological model of the river system to assist in modeling of environmental impacts.

Because of the rapid changes in water level with peaking operations, water quality impacts are best assessed using sites that continuously record temperature, dissolved oxygen and conductivity, at several sites downstream of the power station. Sites should be in conjunction with a gauging or water level station so that reading can be related to flow/level changes, and ideally upstream and downstream of significant tributaries.

Investigations of the impacts of peaking operations on fluvial geomorphology require particular attention because the dominant geomorphic processes can vary considerably depending on the type of discharge regime from the power station. These investigations can employ a number of different approaches. Development of a sediment budget for the downstream environment provides a valuable framework for more detailed reach-specific assessments, as does mapping of riverbank and bed attributes using a hand-held GPS to identify those zones most susceptible to bank erosion. For existing schemes, broadscale geomorphic change in over time can be assessed using comparative aerial photography. Changes to channel profile, depth and channel geometry can be assessed using repeat survey cross-sections. Changes to bank stability and profile can be assessed using erosion pins and photo monitoring. Scour chains in association with erosion pins offer the ability to show maximum scour that occurred during the period between erosion pin measurements. Water samples analysed for suspended sediment concentrations at different points in the river, particularly with continuous autosamplers, are valuable where rivers transport fine-grained sediments.

Further techniques can be employed for predicting the fluvial geomorphic impacts of peaking operations for proposed hydropower projects. Sediment transport capacity of the flow regime can be assessed with dedicated experiments and hydraulic calculations requiring good particle size data and hydraulic characteristics at a cross-section. Penetrometer readings of sediment banks can provide an indication of bank cohesion and strength. Piezometers are a valuable tool to determine groundwater changes in the near river sediment banks in response to changes in river level, so that degree of bank saturation, pore water pressures and degree of risk of drawdown seepage induced erosion can be assessed, often with the aid of computer models. Close investigation of the inter- relationships of riparian vegetation composition and cover with bank stability processes is essential in any investigations.

Investigations of the impacts of peaking operations on riparian vegetation require a basic broadscale mapping exercise of riparian plant communities, and more site-specific surveys of cover and abundance of plant species using a quadrant based approach. Quadrants need to be located in a profile up the bank so that they can be related to different water levels and inundation times. Additional riparian vegetation investigations should encompass assessments of recruitment within each survey quadrant, sampling and analysis of root mat densities in different bank sediment types, and assessment of the contributions of mosses or ground cover species to stream bank stability.

For assessment of hydropeaking impacts on macroinvertebrate populations, investigations should consider species presence/absence, species abundance, habitat availability and shear stress. Several techniques exist to obtain samples for identification. A rapid presence/absence assessment can be undertaken using kick-net sampling in riffles, with samples identified to the family level, and ideally this data would be fed into a predictive bioassessment model which can compare observed taxa to expected taxa and thus provide a rating of degree of impact. Considerable work must go into the development of a bioassessment model if no appropriate model exists. Macroinvertebrate abundance can be assessed using quantitative ('surber') samples that are typically identified to genus level, and in cases to species level to identify any threatened species. Habitat availability analyses requires two data sets-hydraulic data (e.g. velocity, depth, substrate characteristics) collected in field surveys from representative transects across the river under power station on and off conditions, and habitat preference data for key aquatic taxa derived from either the literature and/or from field sampling – to derive plots of 'weighted usable area' for different flow levels. Finally, shear stress analyses can be undertaken in the field by placing hemispheres of known densities on the stream bed and observing their movement under changing flow conditions, an exercise that requires diving and so safety is a prime consideration when considering this technique.

Assessment of the impacts peaking operations on fish are species are largely based on field fish surveys. Backpack electrofishing is often chosen as a standard sampling method. It allows for a repeatable approach with minimal mortality rates, has known biases, and offers a method of comparison between sites. Results can be standardized into a comparative Catch Per Unit Effort figure for each visit to each site, and site ordination, ANOVA and other statistical analyses conducted. Habitat availability and preference should also be undertaken as per the macroinvertebrate assessments. Site selection should include significant tributary streams as well as the mainstem river, and particular attention paid in sampling program design to upstream and downstream of natural flow obstacles to migration such as gorges. It can be valuable to dissect some fish to analyse their food sources, to better enable linkages in fish condition to be made with macroinvertebrate populations.

More specific assessments are likely to be required for significant species such as waterbirds or aquatic mammals, which would vary considerably in different parts of the world.

4 Environmental management and mitigation measures for hydropeaking

A range of management approaches and mitigation measures can be employed to address the potential environmental issues with peaking operations, and investigations of impacts should be directed at identifying and evaluating management options as much as assessing impacts.

4.1 Discipline-specific options and objectives

Water quality –Storage siting and design should consider whether reservoir stratification is likely to occur, and whether a multi-level offtake may be required to ensure release of oxygenated and ambient temperature water.

Air injection in the turbines can ensure sufficient oxygenation of water releases.

Siting upstream of a significant tributary can ensure mixing of power station discharges with water of ambient temperatures to the further downstream environment.

Geomorphology –Physical buttressing of riverbanks;

Reduction of the maximum power station discharge to reduce the phreatic surface gradient in the banks;

Minimising the duration of maximum discharges to reduce the extent of bank saturation;

Maintenance of a minimum environmental flow to lessen scour of the bank toes and reduce phreatic surface gradient; and

Measures that would increase the viability of riverbank vegetation.

Riparian vegetation –Instigating low flow rates for three summer months every year to allow riparian plants to grow and reproduce and for recruitment to occur during the season of greatest metabolic activity;

Ensure 24~48 hour shutdowns on approximately a weekly basis to reduces stresses of waterlogging and inundation (note this would likely occur anyway with peaking operations);

Facilitate regeneration by direct-seeding of the river banks with local riparian species; and measures that would improve physical stability of the riverbanks.

Macroinvertebrates—A minimum flow to ensure that a proportion of the channel is permanently inundated, that snag habitats on the channel margins are inundated, and that channel can maintain a constant macroinvertebrate community when the power station is not discharging;

Management of rates of increase and decrease of power station discharge can slow the rates of downstream river level changes, and thus reduce shear stresses on the bed particularly on the rising limb of the hydrograph by reducing water surface slopes, and reduce incidences of stranding of fish and macroinverbrates.

Fish—A minimum environmental flows would benefit macroinvertebrate communities and so would indirectly benefit that feed on the macroinvertebrates;

A partial or stepped ramp-down would provide cues to the fish of dropping flows before full dewatering of habitats occurred, hence reducing the potential for fish stranding under peaking operations; and

Restocking with native species.

4.2 Options assessment

A number of the management and mitigation options to address environmental impacts of peaking operations involve dedicated water release patterns. Water management options include minimum environmental flows, power station ramp-downs, power station rates of flow increase, reducing maximum discharges, and minimising durations of full gate discharges.

Controls on patterns of release to the downstream environment to address potential impacts to the downstream ecosystem can be provided either through the power station discharges, through a dedicated release valve, or by a re-regulating structure downstream of the power station.

In general, water management options constitute significant constraints on power station operations and can incur considerable losses in generating potential. Large generating turbines may not be able to generate small discharges required for minimum environmental flows, and many have rough running bands that should be largely avoided.

For delivery of an environmental flow, an upfront major capital cost may be preferable to ongoing constraints on discharge patterns. If the siting allows it and the cost-benefit analysis supports it, construction of a re-regulation storage to allow downstream release patterns to be dedicated to environmental management outcomes can be very successful. A re-regulating structure is a dam or weir that impounds the regulated flows from the power station, and allows control over release patterns to downstream of the structure. Mini-hydro turbines can also/alternatively be employed to recover generating capability with minimum flow releases.

A ramp-down or step-down rule for the power station could be compatible with peaking operations. This would be particularly of benefit in reducing seepage-induced erosion in riverbanks, and would also offer benefits to fish to reduce risks of fish strandings.

Ramping up constraints would not be desirable with peaking operations, as they would reduce the rapid start advantage that the hydropower station offers with the provision of peak load. The provision of a minimum environmental flow can lessen the need for a ramp-up rate, as it would ensure that shear stresses are reduced as water levels rise in the downstream river system.

Depending on the circumstances, it is likely that several of the options are utilized as a package. Water management options in combination with localized treatment works can be successful. Localised treatment options include bank protection works, bank revegetation works, local willow control, and fencing/stock exclusion. There may also be site-specific opportunities, such as diversion of part of the downstream flow to lessen the degree of water level rise and fall.

5 Conclusions

In summary, there are a number of potential environmental issues associated with hydropeaking operations, as well as a range of mitigation measures available to substantially address these issues. Potential environmental issues should be thoroughly assessed prior to finalizing the siting and design for a proposed scheme, so that potential impacts can be minimized, and that the scheme can include any mitigation or management measures as part of its design. Many of these measures can also be employed to minimize impacts arising from peaking operations with an existing scheme. Assessment of management measures should consider any possibilities of trade-offs that might arise amongst the different ecosystem components, and should be should be subject to a thorough cost-benefit analysis. ■

Hydro Power in Norway — Development, Political Priorities and Public Opinion

——Lessons learned through more than 100 years of developments

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Abstract: *The production of hydro power from its natural water resources has come to mean more to Norway than to possibly any other country in world. The right to utilize the falling water in the rivers belonged to whoever owned the adjacent ground. The acquisition of water rights is not allowed without a license from the government. Any development is also dependent on a governmental licence. Important conditions such as return of the property to the government without any compensation after 60 years, compulsory delivery of power at production cost and license fees to the local municipalities have been important incentives for the public and political acceptance of hydro power development in Norway during a long period of economic development. Today, Norway is a rich and materially well developed country, and there is no longer any acceptance for further hydro power development. Some of the remaining potential will be utilized for small-scale local developments, but most of it will be incorporated in governmental conservation plans.*

Keywords: *Hydro power; licensing; public acceptance*

1 Introduction

Water is one of Norway's major natural resources. Lots of waterfalls and natural lakes provide excellent opportunities for hydro power developments. The harvesting and transformation of the abundance of water into hydro power has come to mean more to Norway than to possibly any other country in the world. When technologies for producing and using electricity emerged in the second half of the 19th century, Norway was still a dependency ruled by Sweden. But even so, it was in a process of rapid industrialization, and with no coal on its own, it took quickly to harnessing the power of its rivers. What got Norway off to a strong and early start was more than anything else, the favourable distribution of its hydro power resources. There were suitable sites for small scale development available throughout the country. Development could be undertaken on a small affordable scale to begin with increasing in force as the demand base broadened.

In more than a hundred years of hydro power development, Norway has had consistently the highest per capita electricity consumption of any country, and virtually all of it from hydro power. Even in overall terms, then, this small country of 4.5 million people ranks with the world's top hydro power producers. Hydro power has made a major contribution to Norway's economic development, by supporting a strong export industry and as a component of material welfare.

When the technologies for practical utilization of electricity were introduced in the 1880s, Norway was still a poor country not only by today's measure, but also relative to her southern neighbours in Europe at the time. The economy was largely agrarian. Out of a population of close to 2 million, less than a quarter were living in towns. Only 10% of the employment was found in the industry, against more than 50% in agriculture.

Norwegian business and engineering communities were quick in grasping the potential of the new innovations. The building of the first dam started in 1879 and the hydro power station started production only 45 fays after Thomas A. Edison's very first station in Fox River, Wisconsin, USA. The northern city of Hammerfest became the first town in the world to have a municipal power supply system in 1890.

2 Licensing and Local Benefits

Under the Watercourse Act of 1887 the right to utilize the falling water in a river belonged to whoever owned the adjacent ground. This was merely a codification and clarification of legal rights that had developed with the extensive use of water power for local mills etc. over centuries. The water utilization right could be sold off separately from the land. But the owner of the right could not alter the regime or the course of the water to the detriment of others without their permission.

The prospect of profitable hydroelectric development gave the water rights a new value, and made them suddenly the object of trade and speculation. Water fall speculation seemed to become rampant at the beginning of the 20th century, and particularly the participation of foreign investors caused popular concern. Thus in 1906, one year after Norway got its independence from Sweden, the government passed the Industrial Acquisition Law that made the acquisition of certain industrial rights including water falls dependent on a governmental licence.

The Water Course Regulation Act of 1917 came to be the most important law in larger scale hydroelectric power development. Without the right to regulate water flow by seasonal storage, development for regular all-year power production is not possible in Norway. Under this law, regulation of flow by storage is dependent on a governmental licence. Such a licence shall only be granted if the advantages obtained clearly outweigh damage and disadvantage to property as well as to public interest.

In the licence, conditions can be stipulated as deemed necessary in public interest. A main condition for all private investors was that all installations, including the dam and power station, shall revert to the State in good working condition at the expiration of the licence, normally after 60 years. This reversion right has been undisputed until recently, when it has come under pressure from liberal ideas and rules in the European Union. However, the general opinion among Norwegian people and politicians is still that water and hydro power is an everlasting nature resource that should belong to the people. Investors may help to develop and reap the benefits of the resources, and have their fair good share of the economic outcome, but after a certain period the production rights and installations should be retuned to the State.

License conditions also include full economic compensation for any damaged caused by the developer, and obligations toward the public interest such as health, education, local employment etc.. In addition the local municipality is entitled to claim a certain part of the electricity production (“licence power”) payable at production cost only. This part shall not exceed the total need for power in the municipality. In practise the licensee has to deliver approximately 10% of the mean annual production to the local municipalities. The idea was to secure power for local electrification of households and small scale industry. Today, with a fully integrated transmission grid and a liberal electricity market, the municipalities may sell off their part of the production in the market. Some municipalities earn extra money by such sale of power. Others prefer to supply their own inhabitants with cheaper electricity than the normal market price.

The power producer will also have to pay a defined annual fee, based on the potential mean annual production to the local municipalities and to the state. 25%of the total fee is paid to the central government and 75% of the fee is divided between all the affected municipalities, including the reservoir area and some downstream areas.

Another general condition determines a special development fund to the affected municipalities. Within a framework decided by the government, the local government decides the use of the fees and the fund in order to develop local industry and businesses.

Norway’s constitution contains a provision for compulsory purchase or expropriation: “Should the interests of the State or the public require that anyone shall cede any of his moveable or immovable property, he shall have full compensation by the State Treasury. Stipulations of conditions for such expropriation and the procedure for determining compensation (usually by a court of valuation) are incorporated in the water laws and in the general law of expropriation.

3 Public Acceptances

A practice of extensive public hearings before granting a licence has been instituted in Norway. These public hearings and the parliamentary debate on major regulation projects has been the main tests of acceptability to the public.

From the start of the hydro power developments and until 2/3 of the 20th century had passed, the public opinion was quite positive to the hydro power development. The debate was whether foreign investors should be allowed or not, and not on the detriment of nature. Dams and dry river beds did not seem to be of much concern compared to the prospect of getting domestic electricity, first mainly for lightning, and then for new industry.

The cheap “licence power” created new opportunities and was accepted as a very positive step forward for the local community. Other economic benefits, such as the licence fees and taxes, created rapid development of social and economic structures in these small countryside societies. Most of these changes were positive, and people seemed to enjoy the new opportunities.

Smaller developments were mainly for local demand, while others were for large scale industrial development and for large cities. In the middle 1940's there were close to 2000 power stations in Norway, but still not all the parts of the country was electrified. Gradually a national transmission grid was developed and the duty for the local electricity company to secure the local demand eased. Electricity became a normal and always available commodity. Small power stations were closed down, and new larger ones were built.

The larger schemes included larger dams and dry river beds, and the area of untouched nature was gradually reduced. The previous clear ties between development and usefulness became less obvious. In the general public, more people became more concerned about nature detriment and preferred to see the rest of Norwegian rivers untouched by developers, rather than more energy and more material welfare. However, most municipalities were still positive due to the extra valuable income they got from the development and production.

The counter forces conservationists grew gradually in number and strength, from a few NGOs with their main power base among academicians in the towns to a public movement with strong support also in the countryside and gradually even among the politicians in the Parliament. Some controversial development gave large symbolic effects to the conservationists and from 1970 it was fairly easy to recruit large groups of people for peaceful demonstrations and civil disobedience against further developments.

Conservation plans for several rivers and a master plan for further development were introduced, but even so all new development plans became more or less controversial. Finally in 2001, the Prime Minister declared in a speech that the era of large hydro power developments in Norway had come to an end. A total of approx 120 TWh have been developed out of a theoretical calculated potential of 187 TWh.

Small scale hydro and wind power should take care of the future demand. After a few years of small scale hydro power developments it is clear that the environmental detriment for many small schemes is no less than for the fewer big ones. But local people seem to accept more negative effects as long as they also get the positive one of earning money on the development, and it is definitely more difficult for national NGOs to create a public movement against such developments.

4 Conclusion

It is important for any developing county to develop their own legal framework and democratic processes in order to get national and international acceptance for decisions development or conservation. However, the difficult matter of judgement between a development that will give electricity and valuable economic benefits on the one hand and changes, sometimes permanent ruin of a certain nature value on the other, should be a national political responsibility. It is important to secure the national rights of natural resources and a good gain for the local inhabitants in the development area through the national legislation.

It is easy to get local and national accept for development of natures resources as long as there is a general need for economic development and material welfare in the society. When locals feel the positive benefits of a development, they are also willing to accept several negative effects. When the level of material welfare increase, other values like untouched environment tend to be more important. ■

Introduce SHP in China to Rwandan Ambassador

As invited by the Chinese Ministry of Water Resources, Deputy Secretary General of HRC Secretariat Mr. Pan presented a brief introduction of small hydro power in China to Rwandan Ambassador Dr. Rugangazi in Beijing on 28 June 2005. Dr. Rugangazi was pleased to learn that HRC sent a group of specialists to Rwanda for consultation mission on SHP short time ago, as invited by KIST.

Discussion was followed by the both sides on SHP cooperation and other related issues of mutual concern. Deputy Director General of International Cooperation Dept. of the Ministry, Ms Meng chaired the introduction meeting. ■

2005 NHRI International Water Science Summer Campers Visited HRC

From June 25 to 27, the participants of 2005 NHRI International Water Science Summer Camp paid a visit to HRC, spending three happy days in Hangzhou, one of the most famous cities in China, which boosts a long history and picturesque sceneries, and is always compared to “A Paradise on Earth”.

On the first day, taking a boat on the West Lake, all the campers were fascinated by the pretty sceneries; after dinner, rambling along the Qinghefang, an ancient style street, which keeps intact in Hangzhou and serves as an epitome of the long history of Hangzhou, every one took great pleasure in shopping and concluded with fruitful results. On the second day, after visiting the Dayu Mausoleum in Shaoxing, and listening to the story about Dayu, both the founder of Xia (C. 2100~1600 B.C), the first Dynasty in China, and a great hero on flood control, the campers got to know more about the long history of water conservancy in China. Then, the on-site studies have been undertaken in Tinghu SHP station with a rubber dam, and Nanshan SHP station, a multi-function project in Shenzhou. On the last day, the campers visited HRC and its lab, being offered by HRC experts with the introduction on HRC as well as the SHP development in China. All the campers showed great interests, being enthusiastic in asking questions one after another, all of which were well answered by the experts. Before their leaving for Shanghai, the happy campers were warmly embraced by the famous silk market in Hangzhou.

At the time to say goodbye, a symphonic voice echoed: *Long life our friendship.* ■

Discussing on SHP in China

At Flower Harbor Park in Hangzhou

Appreciating Chinese tea culture

At Tinghu Rubber Dam

At Emperor Dayu Mausoleum

At Nanshan SHP Station

2005 Training Course on SHP for Asia-Pacific Region

<Prospectus>

"2005 Training Course on Small Hydropower for Asia-Pacific Countries" is specifically for developing countries under the list of aid to foreign countries by the Chinese government. Entrusted by the Ministry of Commerce, Hangzhou Regional Center for Small Hydro Power (HRC) will undertake the mission.

Sponsored by the United Nations and Chinese government, Hangzhou Regional Center for Small Hydro Power (HRC) was created in 1981, aiming at promoting the SHP development in the world. China has most SHP stations, with much experience in SHP development. In order to disseminate SHP technology, HRC has already held with success 38 training workshops for nearly 700 participants from 70 countries.

1. Objectives: To master the basic theory and principles of SHP development, to know more about the serialization and standardization of Chinese SHP equipment, and to master the method of equipment selection, operation and maintenance, etc.

2. Date: From 20 Oct. to 28 Nov. 2005, Hangzhou, P.R. China.

3. Venue: Hangzhou Regional Center for SHP，Hangzhou, China.

4. Course Contents: Procedures of SHP development, SHP Hydrology, civil structure and economic evaluation, SHP equipment selection, operation and maintenance, electrical design and automatic control technology for SHP station, etc.

5. Training Methods: Lectures, experiments, practice, discussions, field trips & seminar.

6. Medium of Instruction: English

7. Methods for Evaluation: Certificates will be issued to those qualified participants who present the country report on SHP and perform well during the training.

8. Participant's Qualifications and Requirements for Admission:

a. Recommended by the governmental organizations concerned.

b. The applicants should be under 50 years old.

c. At least two years working experience in the hydropower sector.

d. Be in good health with no infectious diseases or handicapped.

e. Be proficient to listen, speak, read and write in English.

f. Prepare a review paper or report on SHP development of the participants' country so as to exchange among the participants.

g. Not to bring family members to the training course.

h. To observe the laws, rules and regulations of P. R. China and respect the Chinese customs during the training.

9. Training Expenses:

a. The Chinese government will bear the expenses of training, boarding and lodging, local transportation, pocket money of RMB 30 Yuan per person per day for those from developing countries during the training period.

b. The expenses of international airfares (including transit fees), medical care, insurance for the participants are covered by the participants themselves.

10. Application and Admission:

a. Nominated by their respective governments, applicants are requested to fill up the Application Form, which should be endorsed by the departments concerned of their respective governments, and submit with valid Health Certificate provided by authorized physicians or hospitals to the Economic or Commercial Counselor's Office of Chinese Embassy (ECCOCE) for examination and endorsement.

b. If endorsed after checking, Admission Notice will be signed and issued to the accepted participants by ECCOCE through the related government departments. With Admission Notice, participants should go through all necessary formalities with all the mentioned documents to China on the registration date.

11. Insurance: The training course organizer dose not hold any responsibility for such risks as loss of life, accidents, illness, loss of property incurred by the participants during the training period.

12. Liaison Address:

a. Economic or Commercial Counselor's Office of Chinese Embassy (ECCOCE).

b. Hangzhou Regional Center (Asia-Pacific) for Small Hydro Power.

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