Several Issues Regarding Developing Rural Hydropower in China

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Editor's note: This article is presented by Mr. Cheng Huizhou, Director of the Bureau of Rural Hydropower and Electrification, Ministry of Water Resources, P.R. China on the "***International Workshop on Attracting Private and Public Sector Participation in Infrastructure (Small-Hydro and Water Supply Sectors***)" held on November 17-18,2003 in Kunming, Yunnan Province, China. The workshop was jointly organised by Yunnan Provincal Government and World Bank.

Ladies and Gentlemen:

Good morning. Thank you for your attention to the undertaking of rural hydropower in China and welcome all sides of investors to develop rural hydropower. The rural hydropower that I talk in the speech refers to small hydropower with the capacity less than 50 MW. I would like to use this chance to set forth several issues regarding developing rural hydropower of China.

I Grand Potential, Distribution and Features of Resources

The resources of rural hydropower of China are very abundant. According to the preliminary statistics of recent check survey, the capacity that can be explored amounts to 130 GW, ranking 1st in the world.

The rural hydropower resources are distributed widely in more than 1600 counties of 30 provinces (autonomous regions and municipalities), which mainly concentrate in western, middle part and littorals of China. Western part, poor areas, minority areas contain over 70% of total rural hydropower resources.

Decentralization of resources is suitable for the strategic development direction of decentialized and distributed power supply.

The moderate scale of rural hydropower is fit for countryside, farmer organizations and private sectors to explore and conducive to increasing farmer's income and promoting the development of rural economy.

To develop rural hydropower will not result in a large pool of water and cause resettlement or submergence. It will also not emit GHG or any harmful gas. Rural hydropower is a clean renewable energy.

II Achievements of Development

When new China was established in 1949, rural areas in China have no access to power. The central government took the guideline of "walk with two legs" to explore rural hydropower in order to address the power shortage. This development was combined with control of rivers and construction of irrigation works. Up to 1990s, most of counties in China have been electrified by rural hydropower. The development of rural hydropower settled the electricity supply to 600 million unelectrified Chinese people in accumulative total.

Over 1500 counties have explored rural hydropower and more than 48000 rural hydropower stations built up altogether. It is predicted that 2.3 GW capacity will be put into operation at the end of 2003 while the total capacity of rural hydropower will reach 30.8 GW and generate energy of 110 billion kWh annually. Both the capacity and annual energy will account for 40% of that of total hydropower in China. Rural hydropower realizes added value from generation and supply at 50 billion Yuan(RMB) and profits 7 billion Yuan(RMB).

According to the deployment of the State Council, Ministry of Water Resources has continually organized the construction of 3 batches of preliminary rural hydropower and electrification counties from 1985 to 2000. 653 preliminary rural hydropower and electrification counties were thus completed. The GDP, financial revenues, farmers' income and energy consumption of those counties doubled over past 5 years and quadrupled over past 10 years. The economic structure was conspicuously improved and the developing speed evidently higher than national average level.

Rural hydropower has become an important infrastructure and public establishment in vast rural areas in China. It is playing and will play the important role in the development of Chinese economy and society.

III Evolvement of Investment Structure

Before 1990 the main financial source of rural hydropower came from national investment. The investment from central government accounted for more than 30% of total investment during the construction of electrification counties.

From 1990 to the end of last century, besides the national investment, other non-public sector also participated in the development of rural hydropower, mainly the private capital, in Guangdong, Zhejiang, Fujian and other regions. Meanwhile foreign investors started their investment in rural hydropower.

At the beginning of this century, more and more non-public investors invest in the construction of rural hydropower station. The proportion of non-public investment ranks comparatively high in Zhejiang, Guangdong, Fujian and other littoral regions.

In this new era, with rural hydropower listed into "Six Small Projects" by our country, rural hydropower needs to expand the investment scale and enrich the construction content. "Six Small Project" is a combination of 6 small/middle scale of infrastructure projects in rural areas recommended by national government. Their characteristic can be summarized as short period of construction, short period of capital return, wide coverage of benefited people and notable effect of income increase. At the same time, Chinese government carries out Project of Substituting Small Hydropower for Fuel as an important method of consolidating ecological project of transforming farmland into forest to meet farmers' household firewood and production energy demand. Rural hydropower belongs to rural infrastructure and ecological protection projects, therefore, the government will increase the investment accordingly.

IV Main Experience

1) Work on the basis of the situation of China. Chinese government adopted the policy of "walk with two legs". During a very long time, the problem of power shortage was addressed mainly depending on local strength and in combination with controlling river and building up irrigation facilities. As the development of rural hydropower not only solve the electricity shortage but also become the strong productivity, complying with the situation of China, the enthusiasm of central government and local people were thus aroused and the development expanded rapidly.

2) Work on the basis of objective rule. Combining tightly the development of rural hydropower with river controlling, rural hydropower is a dragon head in the construction of irrigation works in mountainous region. To develop rural hydropower will not only bring the comprehensive benefits of water resources into full play, but also promote the sustainable development.

3) Insist on the principle of serving agriculture, rural area and farmers. To develop rural hydropower will make contributions to raising rural productivity, increasing farmers' income and promoting rural development after the energy demand of daily life and production were satisfied by rural hydropower.

4) To tightly combine with poverty elimination. In the vast areas of west China, rural electrification transforms the resources advantages into economic advantages, promotes the poverty elimination and realizes the double wins of economic and social benefits.

5) To tightly combine with the ecological protection. Project of Substituting Small Hydropower for Fuel are carried out in those key areas where project of transforming farmland into forest also carries out so that the energy demand for daily life and rural production can be satisfied, while the results of project of transforming farmland into forest can be consolidated.

6) National policy and investment support. Chinese government sets up the policy of "self-construction, self-management and self-utilization", "rural hydropower shall have its own power supply areas", "to feed power with power, realize the rolling development". Maintains the value added tax of rural hydropower at 6%. Government has put into a large amount of investment in rural hydropower.

V Development Opportunities

1) Great attention was paid to ecological safety by each country of the world today and focus on GHG emission. International community will attach more and more regard to energy structure adjustment, promotion of renewables and reduction of carbon dioxide.

2) Chinese government carries out the strategy of sustainable development, plan the harmonious development of human beingand nature as a whole and take measures of project of transformingfarmland into forest and other ecological protection projects. Project of Substituting Small Hydropower for Fuel will be carried out to meet the farmer's fuel and rural energy demand. According to the plan, up to 2020, the capacity of small hydropower station for substituting fuel will amount to 24 GW.

3) China attaches great attention to the issue of "agriculture, countryside and farmer" and plan the development of town and countryside as a whole. Rural hydropower has been determined to be an important small and middle scale rural infrastructure and public facility, which will be provided with national support.

4) China implements the strategy of developing west and plan regional development as a whole. Rural hydropower is very abundant in western part of China. To develop rural hydropower resources is an indispensable part of strategy of developing west.

5) Water resources will continue getting high attention and support from the government. Rural hydropower as the dragon head of irrigation works of mountainous region will realize sustainable, rapid and healthy development.

6) The State Council has instructed MWR to organize the construction of Hydropower and Rural Electrification Counties to raise the electrification level and meet the energy demand of rural economy and society. Up to 2020, 2-3 GW capacity of rural hydropower should be put into operation annually.

7) Country will steadily push power sector reform to decentralize the monopoly on power market. An equal, competitive, open, orderly and healthy power market system with a separation

between government and enterprises will come into being. The environment of rural hydropower market is improving gradually.

VI Problems and Risks

1) Unorderly development of rural hydropower is very severe. Many hydropower stations do not accord with the comprehensive planning of river basin and hydro potential development. Some river basins are even trenched on viciously preventing from equal competition. Some multi-purposed projects with the benefits of irrigation, flood control and ecological benefits have been explored as a pure commercial power generation projects; some developers reduce the installed capacity of stations defying the hydro potential planning but according to their own financial resources; some developers at will choose the site not obeying the rolling planning of rural hydropower, therefore, resulting in a great deal of resources waste and even affecting the safety of flood control, irrigation, drinking and ecological water supply.

2) Severe hidden safety trouble exists in structure of some projects which have not passed the appraisal and approval of water resource authorities. The "Four-nothing" projects which disobey basic construction procedure without approval, design, acceptance and management stand out seriously and some even have caused the fatal safety accidents. Recently MWR just finished cleaning up "Four-nothing" hydropower stations, and many stations were smelled out. Those stations that have severe hidden safety trouble form a serious threat on people's life and belongings.

3) Design market, equipment market and construction market are in urgent need of regulating. In recent two years, due to rapid development of rural hydropower, sector management was kept vacant or difficult to keep in pace with the development of rural hydropower. Some unqualified design institutes participate in the design field of rural hydropower sector; some factories, workshops that are not qualified or with a low technical capacity and even individuals would pull a large amount of equipment manufacturing work into arms; some unqualified construction enterprises also took charge of rural hydropower work. All above causes severe hidden safety trouble to construction, equipment and production of rural hydropower.

Regarding those problems above, MWR and concerning sectors are taking effective measures to straighten out and regulate.

4) With the steady advancement of power sector reform, separation between transmission and distribution is not listed in the agenda, and the monopoly of grid still needs decentralizing. Some hydropower stations can generate but are not allowed to do so, some are allowed to generating but is not accepted by grid. These phenomena still exist in some areas.

5) Although the State Council has issued the new power price policy, the new power price mechanism still needs time to be established.

6) Legislation of rural hydropower lags far behind. ***Regulation on Rural Hydropower*** has not been enacted. There is no legislation support on the development of renewables so far.

VII To Fully Develop the Role of Rural Hydropower in Social and Economic Development

In the new era, Chinese government puts forward a grand goal of building up a well-off society, of which the difficult and crucial point is in rural areas, especially in the vast western part where the rural hydropower resources are rich. Therefore, it is necessary for rural hydropower to bring its advantages into a full play to promote the development of economy and society, and provide the effective support to building up well-off society.

1) To Strengthen the construction of rural infrastructure and improve the life and production condition of rural areas. To develop rural hydropower, improve the facilities of power generation and supply gives the drive to rural economy and society. Meanwhile, to accelerate the controlling of rural hydropower and increase the controlling level of flood prevention reservoirs for increasing the ability of agricultural irrigation and water supply to improve the life and production condition in rural areas.

2) To Increase the farmers' income. Farmers can increase their income by putting money or labor into the construction of rural hydropower, which can bring along rural product processing, local special resources development, construction industry, tourism and transportation industry. It can also transform the surplus labors into useful workers. The severe poor areas can eliminate poverty and increase farmers' income by exploring rural hydropower with the help of increase of government financial subsidies.

3) To create more GDP and financial revenues. To develop rural hydropower is to transform the resources advantages into economic advantages, which could create a great deal of GDP and financial revenues and bring along other resources and sectors development, as well as complete the rural economic structure adjustment, improve its optimization and promote the rural economic development.

4) To protect and improve the ecological environment. Rural hydropower can fully develop its advantage of low cost and further lower the present power price to meet the farmers fuel demand and rural energy demand so as to protect forests and vegetation, consolidate the results of the important project of transforming farmland into forest and other ecological projects.

5) To provide more and more renewable energy for national economic and social development and improve the energy structure.

Thank you. ■

Instructions on the Technical Modernization of Rural Hydro in China

Ministry of Water Resources of the People's Republic of China

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. The "Instructions on the Technical Modernization of Rural Hydro" bring out some objectives and requirements as follows:

(1) Rural hydropower plants

— Much attention should be paid to the cascade and rolling development of a certain basin, and the cascade hydropower station should be designed and built according to the comprehensive programming of this basin. Priority should be given to develop those hydropower stations with at least seasonal regulation capability, and pumped storage power plants should be developed as appropriate.

— New hydropower plants should be designed and constructed according to the requirements of unmanned control and operation (or with a few operators on duty). Those stations built before the 1990s should be programmed for renovation or upgrading in line with the overall objectives. Generating units past their service life and that cannot meet the requirements even if technically upgraded should be discarded for rebuilding or forcibly put out of service.

— Integrated planning and design should be carried out for the renovation of hydropower plants. The output and efficiency of units can be improved, and service life extended through improvements to the hydraulic structures, adopting a high efficient anti-cavitation and abrasion-resistant runner, upgrading the generator insulation, bettering its cooling conditions, applying SCR or brushless excitation technology, gravity butterfly valve and plastic tiles. Meanwhile, the automation of hydropower plants can be improved by renewing or renovating the supervision and control devices and the automation components.

— New high-efficiency turbine-generator units should be applied. The suitable type of unit should be selected according to different water heads and discharges. For the detailed selection method and principles refer to "The Runner Type Series of Medium and Small-scale Kaplan and Francis Turbines" (JB/T6310-92), and "The Type Series of Cross-flow Turbines" (JB/T7640-94), and also consider the existing proven runners of manufacturers.

— Hydropower plants with total installed capacity of 5 MW and above should use open and distributed computer-based supervision and control system. The governor, excitation device, and the oil, water, air and D. C. systems inside the plant, and gates should adopt microcomputer-based systems for their supervision and control. The digital communications between the computer-based supervision and control system and the control units of devices can be carried out through the main communication line at site, serial communication or I/O modes.

— For hydropower stations with total installed capacity of 5 MW or less, the centralized and decentralized computer-based supervision and control system should be combined together. The DC system should communicate with the computer-based supervision & control system. The governor can adopt microcomputer-based type or oil-pressure actuator. The supervision and control for the in-plant oil, water, air and other systems can adopt simple-structured automatic relay control devices.

— Inside hydropower plants with a generator voltage of 400 V, the simpler integral compact supervision and control system should be adopted. Energy-storage for the turbine's actuator can be chosen to be in the form of high-pressure nitrogen cylinder or high-pressure oil. Standardized hydraulic components should be adopted to reduce the maintenance cost and the space occupied.

— The oil, water, air systems and other auxiliary devices inside the plant should be integrated with the main machine for their control, so non-maintained of easily maintained devices or equipment are preferred.

— Inside a power plant, the automation components will play a key role in the unmanned operation of this station, so mature, qualified products which also reach national standards and are fit to be operated in a humid environment should be selected for application. Meanwhile, much attention should be paid to improving the working environment, which must meet the requirements specified in the operation manual. For the oil-water mixture sensor, the liquid-level transducer, the flow transducer, the pressure transducer and the position transducer, those products with 4-20mA modular output or serial communication interface should be selected. For hydropower stations with a relatively large capacity, a gear type and/or the residual voltage should be adopted for speed measuring. The pressure and the liquid-level transducer should adopt a kind of integral structure in which the capacitor type or the diffusive-silicon piezo-resistor is combined with a special signal amplification circuit. The 4-pass ball valve is recommended as the multi-passage electromagnetic valve, and the electromagnetic valve for cooling water should be of the active thermal diffusion type. Cu50 or Pt100 should be used for the temperature sensor, and the temperature data logging devices should be equipped with RS485 or RS232 communication interface.

— In rural hydropower plants, the main electrical connection should be as simple and reliable as possible. Products with high reliability, low fault occurrence, low maintaince requirement, or even non-maintaince properties should be selected for use as the main electrical devices. Examples are the new type energy-saving transformer used as the main transformer, the dry type transformer adopted as the excitation transformer or the plant-service transformer, the vacuum circuit breaker or the SF6 circuit breaker and the zinc oxide lightning arrester. In summer there is serious condensation inside the power plant, so a generator with F or above insulation grade should be adopted. For those rural hydropower plants located in the hilly areas, there are many occasions for them to be attacked by lightning, so much attention should be paid to mitigating lightning attacks, and earthing design and construction.

— Microcomputer-based auto quasi-synchronizing device or the microcomputer-based relay protection device should be adopted.

— Digital or impulse type electrical energy meters are recommended for metering the electrical energy of the hydropower plant.

— For hydropowerpants with a large capacity, the fibre-optic digital instrument transformer and its new automation technology with a low volume and strong anti-interference capacity should be actively recommended.

— As for hydropower stations equipped with a computer-based supervision and control system, the database structure should be of open type, and through reserving communication interfaces and using standard communication protocol, the requirements of dispatching automation can be met, and remote terminal unit (RTU) are not necessary.

— The computer-based supervision and control system inside the hydropower plant should gradually lead to economical operation of the whole station, and cascade power stations can realize optimum dispatching among different cascades. At the same time, communication interfaces should be reserved for connections with other systems (such as water regime forecast, dam safety detection, visual supervision and control, fault diagnosis and status inspection), so that data sharing and information management inside the whole plant can be achieved.

— The structural design of the powerhouse should gradually move towards standard modules, and the building style, form and internal and external decoration must be compatible with the surrounding environment, and aim to beautify the environment and develop tourism. The power plant should be sealed against dust, pests and small animals. During the construction period, the gate in the powerhouse for equipment access should have a framework structure and adopt lightweight removable materials. A permanent large gate should then not be designed any more, and all these gates can be blocked after construction. The arrangement of secondary panels and cubicles is a challenge to the traditional design mode, and a transparent closed equipment corridor can be built. When renovating old plants, attention should be paid to adopt the same panel shape and same color.

(2) Dispatching automation system

—The plan for the dispatching automation system should be formulated according to the development program of the local power grid, and for the master station, communication channel and remote terminal unit (RTU) of the dispatching automation system, the function requirements, technical norms, equipment (hardware/software) programming and the step execution plan should be drawn up.

—The basic functions of a dispatching automation system include the system control and data logging

(SCADA), and the management and application functions for the dispatching operation should be taken as a selection. When selecting these functions, the actual demands on management should be taken into account. Status estimation, current calculation, line loss analysis, load forecast, fault analysis, safety analysis and reactive power optimum operation and management and other high-level applied software should be configured where relevant, and also put into practice.

— When selecting the system platform, the operation conditions of the system platform which has been put into use in that area should be examined, so as to meet the demand of inter-communication among systems. Hardware equipment with superior properties and low price should be selected, to ensure the system is highly safe, reliable, practical, open-structured, extendable, easily-applicable and flexible.

— The dispatching automation system should adopt a standard communication protocol, and it is suggested to adopt the professional standards of China's power industry, "Standard of Basic remote control Tasks" DL/T634-1997 (equivalent to IEC-60870-5-103 protocol), the "Circulating Remote Protocol" (DL451-91) and the "Application-level Protocol on the Real-time Digital Communication of Power System" (DL476-92).

— For some counties which plan to construct a distribution automation system at the same time, the scheme for the integration of dispatching and distribution should be considered, and for others which plan to set up a distribution automation system in the next few years, consideration should be given to including capacity in the dispatching automation system for extension to the distribution automation system.

— The dispatching automation system should be able to interface with the dispatching information management system and the distribution automation Master station, and meanwhile, it can be connected to the management information system (MIS), the water-regime measuring and forecast system, and the dam safety monitoring system, and its interface safety should meet the requirements of the "Safety of the Computer-based Supervision and Control System and the Data-dispatching Networkin Powergrids and Powerplant", to ensure the safe operation of the power grid.

(3) Other matching power grids

— Building a high-voltage powergrid mainly based on 110 kVnetwork, with reasonable structure and simple and reliable arrangement, and which is also flexibly operated with adequate power supply capacity is suitable for meeting the long-term demands of load increase and rural hydro development.

— In cities the arrangement of 10 kV dispatching power grid should adopt a looped network structure with double power sources, which can be operated under open loop. The distribution network located in rural areas will still mainly adopt a radiative structure. A main line or a sub-line which is relatively long should be equipped with a tap changer or branch switch, and other switching and control devices should be actively applied such as the intelligent looped network cabinet (RMV), the automatic recloser, the automatic sectionalizer, the feeder remote terminal unit (FTU) and the transformer mesure and control unit (TTU), so as to realize feeder automation.

— The trend for rural substation is to develop as a small outdoor structure, and in cities, a containerized compact substation can be adopted.

— New substations to be built should be designed in line with the requirements of unmanned operation, and the aged ones should be gradually refurbished with automation systems to achieve unmanned control(or fewer operators on duty). Priority should be given to the use of a comprehensive automation system with hierarchical structure to meet the measurement, protection, control, regulation and communication demands of substations. Standard communication protocols should be applied among the units themselves, and between the substation and the dispatching unit. (For any special communication protocol, the detailed text should be provided). Additionally, attention should be paid to the compatibility, expandability and the upgrading capability of the software and hardware.

— An unmanned control substation may not be equipped with a fixed main computer, but at site there should be some interfaces reserved to connect to the main computer for commissioning. If necessary, a perimeter alarm system and a visual surveillance system can be installed.

— As for substations with voltage of 35 kV and above, the energy-saving on-load regulation transformer should be extensively applied. The distribution transformer should be of the low energy-consuming type with superior technical properties, or a completely sealed transformer or an amorphous alloy transformer. The high-energy-consuming transformers that the government has ordered to be put out of service should be replaced in the next few years.

— For newly built substations, the vacuum circuit breaker, SF6 circuit breaker or other advanced switch equipment should be adopted in line with the voltage grade, and oil switches should no longer be adopted. 35 kV and 10 kV voltage and current transformers should be of resin type. For the voltage levels of 110kV and above, gas-insulated switchgear (GIS) can be selected for use. The oil switch devices used in early times should be discarded gradually.

— According to the system requirements, a reactive compensator with suitable capacity should be reasonably installed, and a reactive auto voltage control device should be erected.

— The use of microcomputer-based protection devices and microcomputer-based auto safety devices should be popularised.

— The use of zinc oxide lightning arrestors should be popularised.

— The distribution cubicle integrating functions such as protection, control, metering, reactive compensation and lightning protection should be adopted for the distribution system in cities.and towns.

— Optical-fibre digital instrumental transformers, optical-fibre digital substations and other new technologies should be popularised.

(4) Distribution automation

— Pilot projects of distribution automation should be actively tried out, and then applied extensively. The distribution automation scheme and its equipment should be selected according to the local economic development, load type and its requirements on dependability. Priority should be given to the SCADA system, the distribution automation (DA) of feeders, automatic mapping/ feeder management/geographical information system (Am/FM/GIS) and the remote meter reading system.

— In the distribution automation system developed at the initial stage, attention should be paid to the selection of the operating system, the database management system and the network system with excellent open characteristics, and in design, some principles should be noted, such as standardization, openness, integration and expandability. Equipment with modularized design should be adopted as far as possible, and the demand for standard interfaces to expand and upgrade functions should be met.

— The design for the master station of the distribution system should abide by the national or professional standards, and it should be endowed with superior properties such as safety, reliability, practicality, expandability, openness, fault-tolerance, and meeting the requirements of the power system for real-time performance. In principle, it should be designed integrally with the dispatching automation system, and interfaced with the management information system. The data exchange among various systems should observe a unified interface norm, so as to use the same information sources, mutually share the information and simultaneously renew the figures and data. Before the dispatching automation system has been set up, the distribution automation system should not be implemented in advance.

— The remote meter reading system should be initially carried out, and then gradually popularized if practical. The communication channels of the remote meter reading system should be considered as a whole when planning the communication channels of the power grids, so as to try to realize their mutual sharing, and additionally a certain development in the future should be considered.

(5) Information management

— The management information system (MIS) consists of production, finance, manpower resources, power sales, office automation and other sub information management systems, and much attention should be paid to practicality and compatibility when developing the software of such systems. Therefore, it is suggested to adopt object-oriented technology, so that the software can adapt to changes in organization structure, management mode and operation flow, and extend the life span of the software system.

— Enterprise resources planning (ERP) should be popularized, and the ERP platform should be set up with the full use of the information from MIS and SCADA systems. The technical support system of the power market could be initially adopted, so as to meet the requirements of "price competition for selling to the power grid", reduce the operation costs of enterprises and improve the economic benefits.

(6) Communication system

— The communication system should meet the demands of the power system for its safe and economical operation, and surplus capacity should be suitably set aside to meet the requirements for expanding new communication businesses.

— The design of the communication system should stick to the principles of being advanced, openness, safety, expandability and practicality. This system should adopt the mainstream technology and mature products, and can be suitably state-of –the-art. The network and equipment should support the standard interfaces, and extensively applied standard protocols should be selected so as to realize reliable interconnections with other systems concerned. The key parts of the system should have redundancy.

The communication devices and the power source should be highly reliable, and be able to support the smooth upgrading of the system, and meanwhile, it must be guaranteed that business will not be affected during network expansion. The system should be simple to operate, easy to maintain and convenient to manage. For the sake of meeting business demands, the optimum performance-cost ratio should be reached.

— Key networks should adopt optical fibre for communication as a first priority, and the branch communication network should mainly adopt power line carrier technology. When the cost-performance ratio is very good, then the wireless spectrum-spreading device is recommended, with the telephone channel taken as standby.

— Inside the communication network, the exchange, transmission and interfaces should all conform to the national standard, ITU-T norms or other related professional standards.

— During the construction of the communication network, safety measures should be adopted accordingly, so as to meet the requirements specified in "The Safety of the Computer-based Supervision and Control System of Power Grid and Power Plant, and the Data-dispatching Network". ■

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The smaller the ratio is, the more water could be lifted. Although it is difficult to get the exact water output due to the different ratio, resistance of water head loss, operation frequency adjustment and the water level in the feeding tank and water level in the discharging pond, etc, theoretically there is a formula available to calculate the lifted water output:

$q = \eta \cdot h \cdot Q/H$

Where:

- q: quantity of the water lifted (litre/second),
- Q: water flow into the hydraulic ram (litre/second)
- H: water drop of the water resource (metre)
- η: efficiency of the hydraulic ram itself
- h: water lift (metre).

According to the data got from the lab experience, the efficiency of the hydraulic with 100mm of the feeding pipe's diameter, varied with the h/H ratio, which is shown in the curve in Fig. 2, (source: "Die Pumpe", 1963). The above curve shows that the higher the ratio (h/H) is, the lower efficiency the water lifting system has. Therefore, the recommended ratio will be 5 -15, according to the local resource and water demand. In theory, the water could be lifted to the height which is 30 times of the water drop, for instance, with the water drop of 4 metres to lift water to the place with 120 metres high. But in reality, the water lifted is so little that doesn't make any sense for the practical use.

4 Conclusion

Since 1987, Zhejiang Provincial Science and Technology Department (ZPSTD) have co-operated with Bremen Overseas Research and Development Association (BORDA) to implement several projects sponsored and co-financed by European Union, German Federal Government and State Government of Bremen in Germany for the hydraulic ram demonstration and dissemination in the mountainous and semi-mountainous areas in Zhejiang Province and other provinces in P. R. of China. A remarkable result has been achieved in the implementation of the projects. Over 500 sets of the hydraulic rams in 4 different types were installed and operated for the water lifting in the irrigation and decentralised domestic water supply for households in villages.

In the practical application, the hydraulic ram shows strong advantages which are simple in installation and operation, easy in the maintenance and very reliable in the operation and hardly repairing necessary. As proven by the practical application, the hydraulic ram is an appropriate device for water lifting in the mountainous and semi-mountainous areas where there is rich hydraulic resource. This technology has a unique function in the energy conservation and e¡î¡îìnvironment protection due to its operation without any consumption of conventional energy, such as electrical power or fuel oil. The survey and overall potential study involved in the projects have shown the huge potential of the hydraulic ram application for the irrigation and the domestic water supply for the households in the villages. ■

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Hydraulic ram
— a device lifting water without conventional energy

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Abstract: *In the southern part of China, due to the rich rainfalls and favourably topographical landscape, there is abundant hydraulic energy resources contained in the countless small streams and rivers in the mountainous and semi-mountainous areas. Besides the small hydro power generation which transfers the potential energy to the electrical power, there is other technology available to utilise the potential energy directly for the water lifting in the irrigation and decentralised domestic water supply in the village level. This paper introduces the basic principle of the hydraulic ram operation and describes the applicable opportunities for the hydraulic ram.*

1 General Description

In the southern part of China, the rich rainfall and favourably topographical landscape form an abundant amount of the hydraulic energy which is involved in the countless small streams and rivers. The small hydro-power could transfer the potential energy into the electrical power feeding into the public grid or consumed without the connection with the grid. There is other technology available, to directly utilise the potential energy within the water for the water lifting, which is the hydraulic ram.

In the rural area, there are huge decentralised demands of water lifted for the domestic water supply for the farmers' houses and for the irrigation in the agricultural production. When the water resources is available, the hydraulic ram could be used for the water lifting for both irrigation and domestic water supply without any consumption of the conventional energies, such as electricity or diesel. Although the operation of the hydraulic ram doesn't need any conventional input, it still needs energy input, which is the potential energy contained in the water of the small rivers or streams with natural water drop. This potential energy drives the hydraulic ram to lift the water to the certain height. In certain cases, the water could be lifted to over 100 metres by the hydraulic ram. The applicable water drop, which could be artificially made in some cases to drive the hydraulic ram, could be in the range of 1-7 metres.

2 Operation principle of the hydraulic ram

The output of the water lifted depends on the ratio of the water lift and the water drop (h/H), the type and number of the hydraulic rams installed. If we take a medium sized hydraulic ram (type BIL630) as a example, which is working in the ratio of 10, (2 metres of drop, 20 metres of lift, for instance), the output of water lifted could be around 100 cubic metres per day (24 hours).

The precondition of the operation for the hydraulic ram is the water level difference, e.g. water drop. The water in the river or stream with water drop is the potential carrier. The potential energy in the water is applied to lift the water with the help of the hydraulic ram. It is a process of the transformation from the potential energy carried in the bigger amount of water with lower water drop, to the potential energy again but carried in the small amount of water with higher waterhead. Therefore, in the hydraulic ram system the working fluid to drive the hydraulic ram and the fluid to be lifted by the hydraulic ram are the same one, e.g. the water.

The hydraulic ram alone doesn't work, it has to be involved in a system which consists of feeding tank (or water collection chamber), feeding pipe, fixing foundation, delivery pipe, etc. shown as Fig. 1, the system of the hydraulic ram.

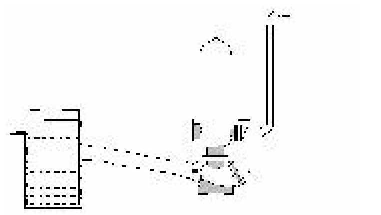


Fig. 1 hydraulic ram system for water lifting

The hydraulic ram operation is based on the "water hammering effect" which was discovered and applied in the hydraulic ram by a British (John Whitehurst, a member of Loyal Academy in Derby). The hydraulic ram operation was designed to apply the water hammering effect to lift the water to the certain height. What is the water hammering effect? In a word about the water hammering effect, when flow is stopped suddenly, a high pressure will create in the water, like a hammer hitting inside the pipe.

The hydraulic ram has simple structure, consisting ram body, air

[*] *Ma Chi is a professor in the Business and Management College of Zhejiang University of Technology.*

vessel, discharging valve and delivery valves which are the only moving parts in the hydraulic ram. These moving parts don't need any lubrication and observation in the operation.

To start the operation of the hydraulic ram, the discharging valve is kept open with a handle; the water runs along the feeding pipe into the hydraulic ram and discharges from discharging valve. The water flow forms and water velocity is increasing. As soon as the velocity reaches to the certain point, the discharging valve will be suddenly closed by the kinetic pressure caused by the water flow hitting. The sudden stop of the water flow creates the water hammering to push the water at high pressure through the delivery valve into the airvessel and compress the air in the air vessel. With the air pressure, a part of water is pressed through the delivery pipe to the height and the delivery valve is closed at the same time.

The high pressure in the chamber beneath the delivery valve, created by the water hammering, is released in pushing the water into the air vessel and overcoming the resistance along the inside wall of the hydraulic ram, delivery valve and the pipe, the pressure is decreased inside the chamber beneath the delivery valve. Due to the decrease of the inside pressure, the discharging valve is open automatically by its own weight. The water from the feed tank (water resource with water drop) runs into the feeding pipe by gravity and the new cycle begins. The continuous repeat of the cycle, the water is lifted by the water hammering effect.

Between the twice opening of the discharging valve, the water flows inside the hydraulic ram and completes a cycle to realise the water lifting. The whole cycle consists of three steps described as follows.

- **First step**

Due to the opening of the discharging valve, the water flows from the feeding tank (water collection chamber) through the feeding pipe and runs out of the discharging valve and the velocity of the water flow is increasing. In this case, with the self-weight of the delivery valve and the pressure of water above, the delivery valves in kept close.

- **Second step**

The water velocity reach to the certain point (the designed velocity), the discharging valve is quickly closed by the kinetic pressure caused by the water flow. Quick close of the discharging valve stops the water flow suddenly. Then, the high pressure of the water happens and pushes the delivery valve opened. The high pressure of the water compresses the air in the air vessel and pushes a part of water into the delivery pipe at the same time.

- **Third step**

The compressed air expands and pushes the delivery valve closed and again pushes some part of water to the delivery pipe. The water lifting is realised. The energy carried in the high pressure of the water releases in the duration of pushing the water into air vessel and overcoming the resistant in the inside wall and valve, the pressure under the delivery valve is decreasing, the discharging valve is opened by its own weight.

With the opening of the discharging valve, the new cycle begins. The water drop makes the water flow through the feeding pipe, and the water flow makes the hydraulic ram operate. Therefore, it is a must that the water resource used for the hydraulic ram operation has a water drop in the range of 1-7 metres. The hydraulic ram could not be applied in the case pumping water from well or water ponds, because in these cases, there is no potential energy available in the water to operate the hydraulic ram.

3 Output of the water lifting by the hydraulic ram system

The water quantity lifted is mainly depending on (h/H) the ratio of the water lift to the drop.

(Continued on page 9) →

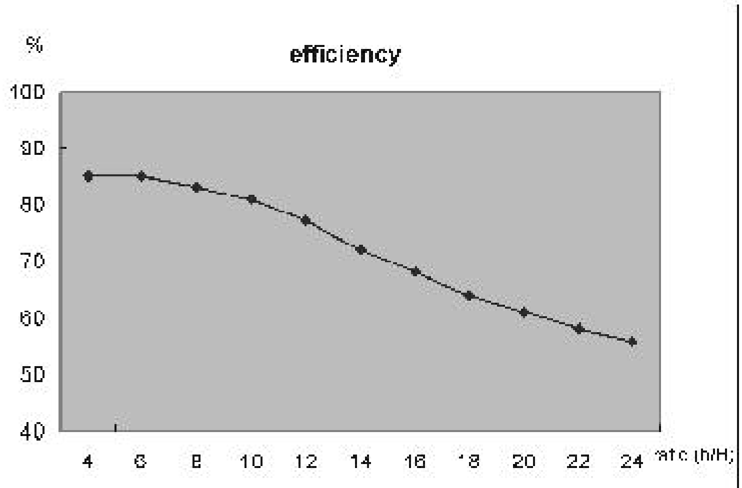


Fig.2 efficiency curve of the hydraulic ram with 4 ' feeding pipe

Speech at the Closing Ceremony of 2003 TCDC SHP Training Workshop

Prof. Chen Shengshui Director of HRC

Issuing the Certificates by HRC Directetor, Prof. Chen

Good morning,

Ladies & Gentlemen:

The 2003 TCDC SHP Training Workshop will soon end at HRC. First of all, I should apologize that I did not involve much in the training activities together with you due to too many meetings and missions I had to undertake recently.

By now over four weeks has past and I am happy to notice that many of you have expressed satisfaction for all the arrangement made for you. Also, I'd like to express my thanks for your good suggestions for future TCDC SHP training workshop. You are now participants. In the future you are expected to play a bigger role in the SHP promotion in your country and serve as the bridge for the SHP cooperation between your country and HRC.

Through your 40 days study in HRC, you have learnt some essential technology and experience related to the development of SHP which is one of the most appropriate energy forms for the vast rural areas of the developing countries. The engineers or specialists from HRC and elsewhere shared their rich experience with you. With all your earnestness, you were active and responsive in class, and very cooperative during the whole training period. For that, we were very impressed. It is expected that you will play a more active role in the exploitation of SHP resources in your own country and for the benefit of your people when you are back home.

Apart from the SHP technology study, you were able to see more about China, to know its people and to make Chinese friends. That is to promote the traditional friendship between China and foreign countries. Obviously, the Chinese language lesson arranged before the SHP presentation helps such exchange and communication. I believe you can serve the important bridge in the cooperation of all fields between China and foreign countries in future.

Today as we are facing globalization of economy, the worldwide cooperation for SHP development would surely form an important sector. This is especially true as far as technical aspect is considered. I assume you are well aware that common consensus has been attained internationally that SHP is an appropriate technology instead of advanced one. As an appropriate technology, SHP is most properly for and could easily be managed by developing countries. In fact, rich experience has already been accumulated in some developing countries. I hope you will understand that China is an excellent example in this field. SHP technology in China is mature and proven, which is wrapped up through construction of more than 40,000 SHP-stations. Furthermore, as China's SHP-technology is also plentiful and versatile, it is suitable for other developing countries in their harnessing SHP potential.

The mission of HRC is to promote the SHP development worldwide by means of training, consultation, R+D, information dissemination etc. We plan to conduct another TCDC SHP training course in next autumn of 2004 and your colleagues or friends working the hydropower sector are warmly welcome to participate. HRC is at the developing stage and the service provided may not be quite satisfactory to all, including arrangement of activities, lodging and boarding, in particular, new lab and restaurant are being constructed in HRC. You experienced much noise and mosquitoes. However, I firmly believe that the participants in our next training workshop on SHP will surely have better environment and facilities in HRC.

You are leaving HRC soon. I hope you keep close contact with HRC and concrete SHP cooperative projects could be set up between us with your assistance. When there is chance, you are welcome to visit HRC again in future.

Finally, I wish you all good health and smooth trip to your own country!

Thank you! ■

Speech at the Opening Ceremony of 2003 TCDC SHP Training Workshop

Prof. Cheng Xialei   Deputy Director of HRC

Good morning!
Ladies and gentlemen,

On behalf of our Director Dr. Chen, I am pleased to be here to give an opening address for 2003 TCDC SHP Training Workshop. I'd also, together with our Honor Director Prof. Zhu, express our warm welcome to you for attending the workshop.

This training workshop has been sponsored by Chinese Ministry of Commerce, as part of China's contribution to South-South Cooperation or TCDC activities.

You may come to HRC at the first time. So I'd like to take a little bit time to introduce about our HRC.

HRC was established in 1981, under joint sponsorship of Chinese government and United Nations organization UNDP/UNIDO. It aims at offering and promoting international cooperation for SHP development in the field of training, R&D, information and consultancy. Domestically, HRC is called National Research Institute for Rural Electrification under leadership of the Ministry of Water Resources. It is a unique research institute for rural hydropower and electrification in China.

HRC has a total staff of 120. It has a 14-floor multi functionary building for scientific research and training, with the total building area of more than 10,000 m^2. A new lab and a meeting hall about 3,000 m^2 are under construction.

So far, HRC has successfully hosted 36 international SHP training workshops with 615 engineers from nearly 70 countries participated in. Meanwhile, HRC specialists have been invited to deliver lectures in Brazil, India, Nepal, Turkey and Greece, etc. Since 1990's, HRC has been making every effort on the transition from TCDC to ECDC. Here TCDC means technical cooperation among developing countries; ECDC means economic cooperation among developing countries. HRC has set up long term and friendly cooperative relationships with more than 30 countries in the world. Feasibility study, engineering designs as well as equipment supply have been implemented for dozens of projects abroad. Two journals, <SHP News> in English and <Small Hydropower> in Chinese, are edited and issued by HRC and have been distributed to more than 90 countries in the world and 2000 counties in China. The international SHP homepage (www.hrcshp.org) started construction from 2002 for providing SHP information to developing countries. HRC has also undertaken a great number of cooperation projects on R&D, such as compilation of numerous SHP norms and standards, development of unmanned control technology for SHP etc.

Through great efforts over the past 20 years or so, HRC has fulfilled all the missions entrusted to it by the UN and the Chinese government. At the beginning of the new century, HRC was given the award of the "Model of South-South Cooperation" by MOFTEC (Ministry of Foreign Trade & Economic Cooperation, now merged into the Ministry of Commerce). The contributions of HRC have been widely recognized by the world community. In a speech delivered at Zhejiang University in mid-October 2002, United Nations Secretary-General K. Annan pointed out: "Right here in Hangzhou, China, you have made use of the Regional Center where you share your valuable rich experience in the field of renewable energy with those from numerous developing countries in the world. China is playing a pioneering role in the regional technical cooperation with developing countries. You developed a lot of cooperative projects not only in foreign countries, but also you have generously implemented training workshops for those from the developing countries."

As you know, after the world energy crisis in the 1970s, SHP, as the most realistic form of renewable energy, was revived in many countries in the world. Thanks to the active role that SHP plays in the supply of rural energy, alleviation of poverty, improvement of the environment and promotion of the rural economy, quite a number of countries have paid great attention to the development of SHP. As an appropriate technology, SHP is most properly for and could easily be managed by developing countries. In fact, rich experience has already been accumulated in some developing countries. We will hold a forum for exchange of SHP experience and technology among us during the workshop.

China abounds SHP resources. The theoretical SHP potential in China is 170 GW, with 120GW as economically exploitable. With strong governmental policy support, outstanding achievements have been made in the development of SHP and rural electrification in China during the past 50 years, especially during the last 20 years. By the end of 2001, 43, 027 SHP stations were in operation, with a total installed capacity of 26, 262 MW. The three batches of 653 SHP-based primary rural electrification counties have been completed. Another 400 rural electrification counties will be building up during 2001 and 2005 as the fourth batch. Half of the land, one third of the counties and one quarter of the population have access to rural hydropower in China. After decades of practice in China, rich experience in construction of SHP has been gained, and its features with Chinese characteristics can be summarized as follows:

— Unique management mechanism: planned by the central government and implemented by the locals.

— Setting up SHP-based rural electrification counties, simultaneously leading to a booming rural economy.

— Promoting poverty-alleviation by SHP construction.

— Putting up SHP-based local grids with their own supply areas.

— Development of medium and small hydropower as an important part of the river treatment work, and an inseparable part of water resources sector.

— Paying attention to environmental benefits and conducting SHP ecological substitution for firewood fuels.

— Multi-layer fund-raising channels, mainly building state-owned SHP stations in combination with a multi-ownership system for SHP stations.

— Developing the corresponding equipment manufacturers for medium and small hydropower, conducting timely training, with self-reliance in solving technical problems.

— Coordinating all parties concerned, adjusting and updating promotional and protective policies.

The achievements and experience gained in China have been recognized and highly evaluated by the world community. Due to time limitation, I could not mention too much here. After listening to all the lectures in the up-coming workshop, I hope you will understand that China is an excellent example in this field.

Over one month study here at HRC is not long, however, I do hope you could benefit from exchange of SHP experience and technology. All of you are expected to become backbones in your own SHP development after going back home and act as a bridge and initiators for the future cooperation.

Here, I'd also like to mention that Hangzhou is a well-known city of long standing in China and had served as capital of China for over 200 years in the Chinese history. With the implementation of reform and opening policy during the past 20 years in China, tremendous changes have taken place around the city. Apart from your study of SHP technology, you will have chance to see and experience what is going on in Hangzhou. And also, you will visit Shanghai—the largest city and port in China and Nanjing to see more about China, to know its people and to make friends with them.

I am anxious that the construction of new building at HRC may cause some inconvenience to you, but I believe a lot of activities such as table tennis competition, dancing party, weekend sightseeing and shopping as well as our net-bar, etc. will make you happy and release your homesick.

Finally, I wish your study fruitful and your stay pleasant!

Thank you for your attention.

■

A Milestone in International Training on SHP

— 2003 SHP Training Workshop Completed

The 2003 TCDC (Technical Co-operation among Developing Countries) SHP Training Workshop was held from 9 Oct. to 18 Nov. 2003 by Hangzhou Regional Center for Small Hydro Power (HRC). Attended altogether 37 participants from 24 countries, covering Asia, Africa, Latin America, Eastern Europe and Oceania. This is the first training workshop on SHP that HRC conducted since the establishment of HRC for so many participants from so many countries.

This training workshop which is the 37th international SHP training workshop conducted by HRC was sponsored by Chinese Ministry of Commerce, as one of the technical collaborative projects among the developing countries. All the lodging, boarding, training, pocket money and the domestic transportation fees were borne by the Chinese government. That is part of the Chinese contribution to the South-South cooperation.

In his speech at the closing ceremony, Director of HRC, Dr. Chen pointed out: "Through your 40 days study in HRC, you have learnt some essential technology and experience related to the development of SHP which is one of the most appropriate energy forms for the vast rural areas of the developing countries. It is expected that you will play a more active role in the exploitation of SHP resources in your own country and for the benefit of your people when you are back home". "Apart from the SHP technology study, you were able to see more about China, to know its people and to make Chinese friends. That is to promote the traditional friendship between China and foreign countries. Obviously, the Chinese language lesson arranged before the SHP presentation helps such exchange and communication. It is not exaggerating to say that you can serve the important bridge in the cooperation of all fields between your motherland and China in future."

Most of the teachers were from HRC. Participants were required to master the basic theory and principles of SHP development, feasibility study and to increase their ability to solve the concrete problems concerning SHP exploitation. The subjects included procedures of SHP development, feasibility study, hydrological analysis, low-cost and simplified civil structures, turbo-generator units and auxiliary, electric equipment design, technical refurbishment, computer application in SHP stations, SHP economic evaluation, etc. Such special topics as hydro power resources in China, renewable energy, hydraulic ram and micro power units were also introduced and evaluated by the participants as beneficial.

During this training workshop, new study tour routes were developed and optimized. Study tours were arranged to Shaoxing, Shengzhou, Linhai, Wenzhou, Haiyan, Ningbo, Nanjing and Shanghai, where the participants felt to have benefited much. In Shaoxing, Shengzhou, Linhai, they visited some SHP stations of various development types including the rubber dam, equipment manufacturers. Visits were paid to Linhai Machinery Plant and Linhai Electric Machine Plant where participants were able to see the whole process of the hydropower equipment manufacturing. On-site discussions and inquired were made concerning the ordering and the service of the hydropower equipment. In Wenzhou, participants were excited to visit the big private company Chint Corporation Ltd which has been fast growing in the recent years. The company is listed No 1 so far in China in the production of low voltage electric equipment. Its production line is highly automatic. The development of Chinese private companies was briefed and the elements of such fast development were explored. The participants were so deeply impressed that they would associate the technical level of the company to that of such global big companies as GE or Siemens. The products were observed as reliable, appropriate and moderate in price. In Haiyan, participants were delighted to be able to visit one of China's nuclear power plants — Qinshan Nuclear Power Company which is the first nuclear powerstation designed, constructed, tested and operated by the Chinese. With the completion of the 2nd and 3rd phase engineering by 2003, the installed capacity would reach 3 million kW. Some African participants expressed that never in their life have they ever seen a nuclear power plant and such experience was very important.

Participants went to Ningbo, visiting a pumped storage station with installed capacity of 80MW. This station designed by HRC in the past few years was put into operation at the end of 1997. It has a big role to play for the station to provide energy to the grids at the peak hour and its financial record all these years after the commissioning is also encouraging.

Also, three days were spent in Nanjing and Shanghai —the largest city and port of China. In Nanjing, participants paid visit to the packaged hydropower units in Nanjing Hydraulic Research Institute and its Tiexinqiao Hydraulic Experimental Base which is China's largest hydraulic experimental base. Such packaged hydropower units are most appropriate for the energy supply to the farmers in the decentralized vast rural areas in the developing countries, and the equipment is reliable in operation and low in price. At night splendid and gorgeous fireworks were launched for participants who enjoyed every moment. Shanghai is a busy and dynamic metropolis of China. With the opening and reforming policy set forth by the Chinese government some 20 years ago, tremendous changes have taken place in that city. A great number of skyscrapers pop up, with its modern and convenient transportation network. Many of the participants commented: "We thought this is not in Shanghai, but in New York or Paris. Before we came to China, we had a delusion that China was a poor and backward country. The buildings there were shabby and indecent. A lot of people were suffering from hunger. We never think that China is now so modern and developed, with its kind and cheerful people. It has set a very good example for the other developing countries to follow in its economic development."

In addition, during the training workshop on SHP, the Fifth West Lake Exposition was conducted at Hangzhou and the participants had a chance to visit office & household appliance exhibition.

During the training workshop, HRC provided a forum for the exchange of SHP experience and technology. The participants were earnest to offer their presentations. Altogether over 20 presentations were made by the participants, introducing the experience and lessons learnt in the practice of developing SHP in their own countries. Some of their presentations are being considered to be issued at the quarterly *SHP News* that HRC edits and publishes. Participants commented, "This forum was important and well organized. Such exchange of SHP information and experience will definitely promote the further development of global SHP".

Apart from training and study tours, sightseeing programs were arranged. With the West Lake Expansion going on, the scenic area of Hangzhou is increased. Though it is virtually not possible for participants to visit all the local scenic spots only at the weekends during this training workshop, the participants were able to enjoy the main natural beauty of some scenic sites in Hangzhou. Such famous sites as Yang Causeway, Flower Harbour Park, Leifeng Pagoda, Xihu State Guest House, Hefang Street, Museums, Dragon-Well Village and etc were visited. Table tennis competition, singing and dancing parties were conducted. What an exciting experience it was!

Equally exciting was the moment when Mr. Pan, the training coordinator announced at the closing ceremony that HRC has prepared and would present to every participant a CD-ROM which contains a briefing to HRC, the details of 2003 TCDC SHP participants, presentations by HRC's lecturers, photos reflecting activities of 2003 TCDC SHP training workshop, one-hour-long selected Chinese traditional master music pieces and the photos of scenery around Hangzhou — a paradise on earth.

HRC is at the developing stage and its service provided may not be quite satisfactory to all, including arrangement of activities, lodging and boarding, in particular. The participants of 2003 TCDC SHP Training Workshop experienced much noise and mosquitoes, our dining room was temporary. However, HRC's new lab and restaurant are being constructed in HRC and we firmly believe that the participants in our upcoming training workshops on SHP will surely able to make use of the better environment and facilities in HRC.

Essentially, it can be concluded that there are two factors constraining the SHP exploitation in the developing countries — the finance and SHP technology. It is abundant in hydro power resources in those countries but the coverage of electricity is still rather low. For example, in Ethiopia of Africa, the coverage of electricity is only around 13%. Further more, the stage of SHP development in most developing countries is still fairly low. According to the questionnaires collected, nearly all of the participants regarded that such SHP training workshops held by HRC were beneficial to them and thus requested HRC run more training workshops on SHP, in future.

In 2004, HRC will implement numerous both domestic and international small hydro power training workshops including two international training workshops on SHP. The TCDC training workshop on SHP Equipment planned will be implemented in Oct. and Nov. The TCDC training workshop on SHP multi-purpose development in June or Sep. 2004 is now under consideration. It is hoped that more hydro power resources worldwide could be tapped in future so that the living standard of the local people could be improved and their local economy could be boomed in the numerous developing countries. HRC is committed to stimulating the development of SHP — a renewable and environmentally sound energy by conducting SHP training programs so as to benefit participants from the developing countries.

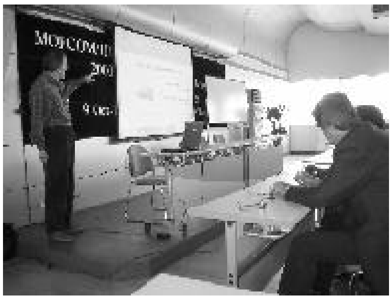
By now the 2003 TCDC SHP Training Workshop has ended and let it be the new start of more future SHP cooperation worldwide! ■

(Written by D.Pan, HRC)

← *discussing with Prof. Zheng*

↓ *presentation by Prof. Zhu*

presentation by Prof. Cheng



SHP Forum

participants at HRC's internet bar

in Chint Corporation Ltd

visit to packaged unit

visit to Qinshan Nuclear Power Plant

at Linhai Machinery Works

evening Party

sightseeing at Westlake state hotel

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 113 issues (bi-monthly), 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.

Subscription rates (1 year): USD40.00

The main contents of issue No.113 (2003 No 5) read as follow.

Strategy and Policy

Program of reform on electricity price

A circular for further strengthening supervision & management of the state-owned assets in rural hydro sector

Rural Electrification

Implementing all-round "subsituting firewood with electricity", exploring the newway for environmental protection

Making SHP a scale-up industry

Planning and Design

Overall design and characteristics of cascade No.1 Hongxi hydropower station in Wenzhou

Design and installation of rubber dam at overflow section of Baikeng reservoir

Analysis on expansion scheme of power station in gate opening in Huaiyin Gate

Technical Exchange

A case study of budget estimation of SHP project according to "Standards of Budgetary Estimate"

Methods to improve SHP economic benefit

Analysis of failure of achieving the design annual benefit for Xiangshuipu hydropower station

Foundation treatment of rebuilding Yinling overflow gate

Testing and revising the velocity coefficient at bank sides of the tailrace of Tanghe reservoir power station

Application of anti-erosion technology with zinc coating in hydraulic metal structure

Computer Application

Analysis and design of computer-based supervision & measuring system at SHP station

Application of unmanned control technology in engineering of "substituting firewood with SHP"

Application of SMER type microcomputer-based excitation regulatior in east Fujian Province

Renovation

Re-upgrading cascade No.1 Hengjin hydropower station

Vibration treatment of KVB37-18 Kaplan turbine unit

Auto air-replenishment of oil-pressure device of butterfly valve and governor

Much profit gained from Luhun reservoir power station after enlarging capacity

International Exchange

A new label for green electricity products

Improving cost-effectiveness of small hydro through intelligent load management

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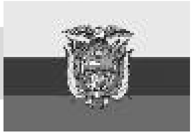


Report submitted by:
Ministerio de Energia y Minas, Ecuador

1. INTRODUCTION

Ecuador, a South American State, straddles the Equator and is characterized by great geographical, biological and ethnic diversity. The country is divided into four regions: the coast (Costa), mountains (Sierra), Amazonia (Oriente), and an insular territory comprising the Columbus Archipelago (Galápagos Islands).

Both sides of the Cordillera of the Andes are very rainy, providing Ecuador with a huge potential for hydropower (around 30 GW technically feasible) which greatly exceeds present power needs (around 2 GW).

The population is about 12,156, 608, with an annual growth rate of 2. 1%. Quito, the capital city, has more than 1.5 million inhabitants and Guayaquil, the main port and town in the country has more than 2 million inhabitants. Estimates for the year 2010 foresee a population of 14,900, 000.

The rate of illiteracy (on average) is 8.4%. In urban areas it is 5.2% and in rural areas, 13.7%. The Human Development Index (HDI) lists Ecuador at the 72nd position worldwide, with a 0.747 HDI. The drinking water coverage is 36.8%, and for sewerage it is 41.8%. The water usage per capita is around 320 litres/day. The main use of water is for irrigation (around 80%). The net irrigable area is around 3,136, 000 ha. The proportion of the population with access to electricity is 92. 7%. As a result of regional conflicts, natural hazards and political instability, the development of Ecuador has been affected by an economic crisis in recent years. As a result of this crisis, the poverty rate has increased to 80% and extreme poverty has doubled over two years. The effects of poverty are felt more seriously in rural areas: 25% of rural people suffer from a critical state of poverty, and 50% from relative poverty (income sufficient enough to meet nutritional needs, but no others); this situation has led to rural depopulation.

2. ECONOMY

Ecuador's economy is based on oil, agriculture, fishing, mining, and the non-traditional export of products such as shrimps, flowers and tropical fruits. One of the factors impairing Ecuador's development is the high level of its foreign debt. By the end of 2001, the total public debt (80%) and foreign debt (20%) reached US$ 14,375.7 million. In the year 2000 almost 50% of the GDP was allocated to paying this debt, and the interest alone in that year amounted to 28% of the total exports. In 1999 interest reached 29% of the total exports.

On 9 January 2000 there was an announcement of the 'dollarization,' that is, an alignment of the national currency, the sucre, with the US$ at the rate of 25,000 sucres per US$.

Before this 'dollarization', inflation rates had reached peaks during the previous decade and up to 60-75% in 1999. These rates are now low, in the order of 10% in 2003. The stabilization and clarification of economical rules should facilitate the long and medium term investments which the hydroelectric sector needs.

In fact, the financial instability of the past 15 years had stopped investments in the hydropower sector, which led to the current inadequate development, responsible for the periodic rationing of power, and the use of thermal energy to meet one third to half of the total needs.

Table 2.1 presents some key economic ratios of Ecuador for the period 1995-2001.

Table 2.1 – Key economic ratios for Ecuador (1995-2001)

Data	1996	1997	1998	1999	2000	2001	2002 (est)
GDP (US$million)	19,156.7	19,760.0	19,710.3	13,769.4	13,648.9	17,982.4	20,504.8
GDP per capita (US$)	1.637,5	1.655,4	1.619,0	1.109,4	1.079,3	1.396,2	1.563,8
GDP growth rate (%)	2.0	3.4	0.4	-7.3	2.3	29.4	12.0
Exports (US$million)	4900	5264	4203	4162	4822		
Imports (US$million)	3571	4520	5110	2737	3160		

Source: Banco Central del Ecuador, Bulletin 2002/05

Table 3.1 – Total primary energy production (TPEP) and consumption (TPEC) in 1995-2001 (values in TJ)

	1995	1996	1997	1998	1999	2000	2001
TPEP (TJ)	878,220	931,140	984,060	1,005,060	984,060	952,560	952,560
TPEC (TJ)	307,220	338,520	328,020	349,440	359,940	370,440	380,940

2.1 Social and political

Immersed in a global economy, Ecuador, since the year 1992, has begun an ambitious privatization programme, and has opened its economy to foreign investment. New legislative actions support a restructuring of various governmental sectors (mainly oil, electricity and communications) to increase their competitiveness and efficiency. The State-owned companies' equity is now part ofthe Fondo de Solidaridad (Solidarity Fund) in charge of administrating these funds before they are offered to the public. The National Modernization Council (CONAM), established in 1995, has the task of bringing this privatization programme into effect, an important part of which is the concession of the power utilities.

3. ENERGY SECTOR

Ecuador is a country with vast hydroelectric resources (30 million MW) as a result of its deep valleys, and it also has large and productive petroleum reserves (totalling 2100 million barrels), significant but not yet exploited natural gas reserves (1050 million m^3), and a small amount of coal (23.5 million tons). Biomass potential has been estimated to be around 835, 000 GWh/year. Some historical figures of primary energy production and consumption are shown in Table 3.1.

3.1 Electricity

The electricity service is Ecuador dates back to 1897. The first hydroelectric power unit was installed at San Ramón, in the province of Loja, and had two 7 kW units. Until 1961, the municipalities were responsible for electricity and no central planning existed at that time to control the 1200 small power plants, mostly hydro, in the highlands and the thermal (diesel) plants on the coast. The Basic Electrification Law in 1961put an end to this chaos, and created the National Ecuadorian Institute of Electrification (INECEL). INECEL managed to organize the sector and implemented the large power plants, constructed the national electricity grid (SNI), and set up the legislative framework for distribution by public power utilities around the country.

In 1999 INECEL ceased to exist, as a result of the Privatization and Modernization Law of 1993 and the Electricity Regime Law, passed in 1996. All its assets were allocated to the Solidarity Fund. The power plants were divided between six private companies, but retained the Government as the major stockholder, one main transmission grid company (TRANSELECTRIC) and 20 distribution power utilities including EMELEC, a privately owned company serving the city of Guayaquil.

3.2 Legal framework and tariffs

The new Electricity Regime Law in charge of CONAM created the National Electricity Council (CONELEC) with responsibility for planning, management and control of the sector, and the National Energy Control Center (CENACE), in charge of the Major Electricity Market (Electricity Exchange Power Pool), where all the transactions take place between the generators (with power capacities larger that 2 MW), power utilities, and large loads. The generating plants with the lowest marginal cost are able to sell first, and then the other ones with higher marginal costs are called upon to connect to the grid until the demand is reached for that hour.

CONELEC regulates the sector, and has the responsibility for servicing the isolated areas, mostly in the Amazon and the Galapagos. Just a few large industrial loads are served directly from the power pool. Domestic consumers are served exclusively by the power utilities in their areas. Independent power producers (IPPs) can sell either to the MEM based on a Power Purchase Agreement (PPA), to the power company or to a large load. No restriction exists for a user to install his own electricity supply and share it with other users, as long as it complies with the regulations of CONELEC and with national service standards.

Prices of generation in US¢/kWh for the year 2001 are as shown in Table 3.2. The prices on the users' side are shown in Table 3.3. An increase rate of 2% per month is in force until the international level is reached this year (2003). The purpose behind the structure tariff is to set prices so as to attract foreign investors to buy the generation and distribution companies, in other words, the privatization of the sector.

3.3 Privatization process and restructuring

According to the Electricity Law Regime currently in force, the Government does not participate in the construction of new power plants, except in isolated areas (Galapagos and the Amazon), leaving this to independent power producers (IPPs). However, uncertainty about the tariff structure, combined with the instability of the political and legal situation in the country, have delayed the construction of new plants. Just a few thermal plants have been temporarily installed by private companies to cover electricity shortages. Ecuador lacks almost 500 MW of power to balance the load increase.

Existing regulations in favour of renewable energies and improving the efficiency in load consumption can be stated just in general terms. The Electricity Law, passed in 1996 had suffered more than 34 amendments up to last year, mostly dealing with the privatization or sale of utilities.

Distribution power utilities are ready for sale, but private investors have not shown a real interest. The Government will retain a 39% share, the workers 10% and the new owner will obtain control of the company with a 51% share in the stocks. CONELEC will continue to act as the regulating and controlling institution in the electrical sector, whereas CENACE will keep its status as a private technical supervisory body in the electricity market.

3.4 Electrical system

Ecuador has an installed capacity of 3270 MW. The effective (available) capacity is 3054 MW. The total number of customers for the year 2001 was 2,503,676, and the energy sold in the same period was 7,965.5 GWh.

3.5 Generation

Ecuador relies heavily on hydroelectric resources to power the country. More than half of the total installed capacity is hydro and the remaining 44% is from thermal sources. The latter is made up of 23. 5% thermal (diesel turbines), 2.3% internal combustion engines, and 17. 2% steam plants.

The largest hydroelectric plants are Paute (1075 MW), Nación (213 MW), Agoyán (156 MW) and Pucará (76 MW).

Paute has a relatively small reservoir with storage for just 15 days at full load. Because of its location it is affected by cyclical periods of low rainfall, thus causing power shortages as was the case in 1995 when hydro capacity dropped to 17% and left cities in the dark for 8 hours a day. Less severe outages occurred in 1996. Scheduled blackouts are not rare in periods of drought during the months of October to March. This plant was part of a whole hydroelectric development planned for the Paute river basin, with two more installations, but a lack of financing has delayed the construction of the upstream Mazar powerplant, which will have a large reservoir capable of reducing the impact of sediments now affecting the Paute plant. It will also increase the water storage.

Two plants, Paute-Mazar (180 MW) and San Francisco (260 MW), are now underconstruction on a concession basis by foreign developers. To compensate for the lack of hydroelectric generation caused by the drought periods, small diesel gas turbines (less than 30 MW) and some second-hand steam plants have been installed, but because the operation cost is high they do not function regularly.

From October 2002, the Machala natural gas plant has been in operation with an installed capacity of 130 MW.

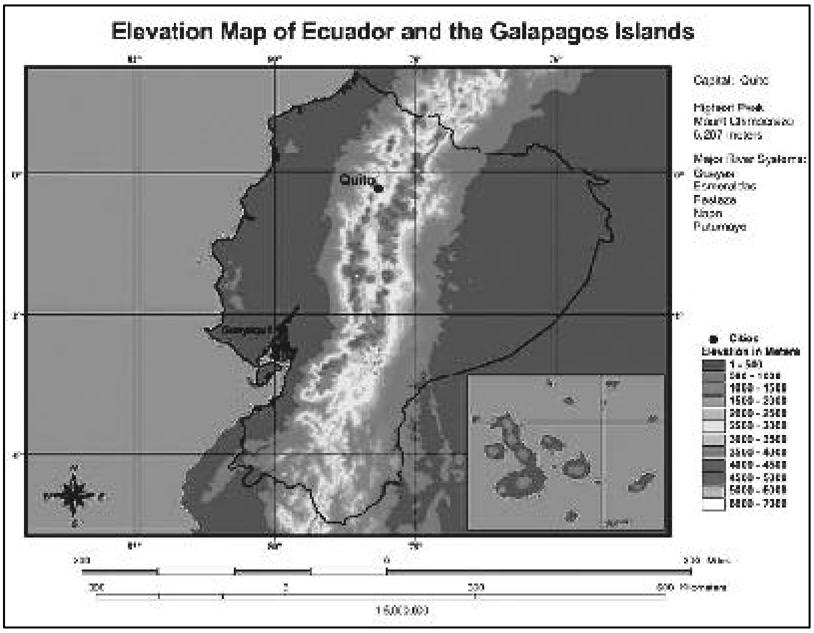
The interconnection with Colombia will permit an exchange of 200 MW (available from January 2003), and the connection with Peru, 150 MW.

Table 3.2 – Generation prices US¢/kWh

	Long term contacts ¢/kWh	Spot hourly ¢/kWh	Average ¢/kWh
Jan-Dec 2001	2.95	6.50	5.30

Table 3.3 – Consumer prices US¢/kWh

Average	Residential	Commmercial	Industrial	Public lighting
6.46	5.94	6.50	6.91	6.78



3.6 Transmission

The transmission of energy through the SNI grid (Sistema Nacional Interconectado) has been carried out by one company Transelectric S.A. since 1999. The interconnected grid connects the main centres of consumption (Guayaquil, Quito and several other towns) to the major production plants by a 230 kV loop-shaped line. The Transelectric SA line is 820 km long with 1170 km in branches. The largest substations are supervised online at the modern SCADA based National Energy Control Center (CENACE), built in 1995.

Transmission losses varied between 3.2 and 8% of the net energy produced between 1992 and 1999. Transmission losses were 3.84% in 2001.

3.7 Distribution

Twenty companies are in charge of the distribution of electricity in Ecuador; they are limited companies in the process of privatization. There are two isolated areas: the Sucumbios and the Galapagos Islands Electric Co, which are not connected to the grid. Distribution losses are of the order of 22.61%.

3.8 Load

Taking into account the number of customers and the energy consumption, the ratios by December 2001 were as shown on Table 3.4. The annual rate of increase in energy is 6.3% and in power it is 5.7%. Customers are categorized as: residential, commercial, industrial, public lighting and others.

It can be noted that the largest proportion goes to residential customers. Annual rates of increase in the consumption per customer type for the past decade (1990-2001) and the forecast increment in the present decade (2001-2011) are shown in Table 3.5.

4. RENEWABLE ENERGIES

The market for installing renewable energy sources (other than large hydro) can be identified basically in the residential sector (urban and rural) as: small-scale wind, thermal and photovoltaic systems as well as micro hydro plants; medium sized plants for communities or industries; and, large plants that can be connected to the main grid based on wind, biomass and geothermal sources.

According to the Electricity Regime Law, plants based on renewable energy sources of up to 15 MW connected to the national grid are entitled to fixed rates (Table 4.1) during a period of 10 years, starting from the commissioning date.

4.1 Hydropower potential

Ecuador has an exceptional hydropower potential: the high maintains of the Andes enjoy heavy precipitation; river flows are high, and the available heads and waterfalls are high and numerous. The theoretical hydropower potential of Ecuador is estimated at 73,000 MW, of which 30,000 MW is considered technically feasible, and 21,000 MW seem to meet the economic criteria of profitability.

The total capacity of all the hydroelectric developments is of the order of 1700 MW; 90% of the hydroelectric capacity comes from the four largest grid connected hydro stations: Paute, Nación, Agoyán and Pucará.

During regular run-off periods, the installed hydropower can satisfy more than 70% of the country´s needs at a moderate price of less than 0.01 US$ /kWh (a marginal cost of 0.002 US$/kWh has even been calculated). The thermal power stations are then used only to supply the areas far from the SNI or during peak hours.

Periods of drought regularly reduce the available hydropower to a quarter or even a sixth of its value, hence leading (in the short term) to the use of thermal power stations to the full, at a higher production cost (0.1 US$/kWh to 0.15 US$/kWh) and causing more significant environmental impacts. This also leads to power shortage and rationing. Power shortages began in 1990. The most severe one took place between November 1991 and March 1992. At that time, several 'booster' thermal plants were built, and the droughts then had less impact.

4.2 Protection of the environment

All activities related to energy (production, transmission and distribution) should be implemented with due respect for their environmental impacts. Environmental impact studies must be carried out by the developers and assessed by CONELEC for all new hydro projects above 1 MW of planned capacity. Special attention must be paid to water management in strategic catchments areas. Catchments areas are managed by the National Council for Water Resources, CNRH (Consejo Nacional de Recursos Hídricos). Under the auspices of the Environment Ministry, CONELEC is in charge of evaluating EIAs. Although the quality of the available studies is quite good, the lack of guidelines for impact studies, as well as the weakness of databases of environmental parameters make the EIA-related work and evaluation difficult.

A good assessment of impacts makes it possible to minimize all the adverse effects on the environment. But these effects will be, in any case, less damaging than those caused by equivalent thermal generation.

4.3 Planned projects over the next 10 years

CONELEC has drawn up a plan for electrification for the period 1999-2009 which is a period of great change: privatization of production and distribution companies, and the construction of civil works on a large scale for the improvement of production, transmission and distribution.

Forecasts of the energy consumption increase are high (7.6%/year on average). This will require great and constant effort by the operators in the electricity sector. Of course part of this increase should also come from the programme of improvements in energy efficiency. However, improvements in distribution and transmission efficiency alone would not be sufficient to meet the increasing demand.

It is estimated that the total population without access to electricity is in the order of 1,250,000, according to the last census (2001).

The demand for power generation capacity is increasing by 100 to 150 MW per year, which corresponds to a consumption increase of 500

Table 3.4 – Customers and Consumption by customer type

Customer	Number	Consumption
Residential	87.44%	33.41%
Commercial	9.92%	17.83%
Industrial	1.26%	28.39%
Lighting	0.01%	8.35%
Others	1.37%	12.03%

Table 3.5 – Rates of increase in consumption by type of customer

Customer type	1990-2001	2001-2011
Residential	3.9%	5.6%
Commercial	6.2%	5.8%
Industrial	3.7%	8.8%
Lighting and others	7.7%	2.8%

Table 4.1 – Fixed rates for renewable energy (RE)

RE Plant type	Price US¢/kWh
Wind	10.05
Photovoltaic	13.65
Biomass-biogas	10.23
Geothermal	8.12

GWh/year. To cope with this, the Ecuadorian Government is promoting the construction of new hydropower plants. The main projects are: San Francisco and Mazar (total 410 MW). Another 104 projects, with capacities of 5 MW or more, will represent 4348 MW of capcity and 22,527GWh/year of energy. Furthermore, 101 smaller projects (less than 5 MW) amount to 78 MW.

Some of these are already being studied or implemented. The large hydroelectric projects can produce energy at a very low cost (often less than US$1000 investment/kW installed) but they will require heavy investments, sometimes exceeding US$1billion. The total period for their implementation (including studies and construction) can reach six to eight years. Large dams are generally required, which will have a significant impact on the environment.

The electricity production from these large projects has to be integrated in the general plan for the whole country, and will require a powerful transmission network; their very size will make them more vulnerable to natural catastrophes (earthquakes, landslides, and so on) and to droughts which can drastically decrease their production.

The small and medium-sized hydro stations are often more expensive (in general, investments comprise between US$1500 and US$3000/kW installed) but they produce energy at a much lower cost than thermal plants. They can built more rapidly (in one to three years) and generally have less impact on the environment. Their decentralization makes it possible to supply isolated areas, while avoiding the overloading of transmission lines. Being more numerous, they are less vulnerable, and can be the basis for the development of local activities and industries.

4.4 Small hydro development

Advantages of small hydro power

The special characteristics of small hydro which make it attractive are:

- decentralized production;
- modular use, involving a large number of producers and consumers;
- zero or low fuel costs;
- low gestation periods, providing quicker benefits;
- economically viable and financially sound, giving a level playing field with conventional energy sources;
- ability to provide energy security to developing economies;
- mature technology;
- continually renewable resource;
- extremely low operational and maintenance costs, with operation generally running smoothly;
- robustness of the machinery;
- high compatibility with other generating sources;
- flexibility of operation and the provision of system benefits;
- no hazards as regards the production sale, hence a regular turnover (a minimum is always guaranteed);
- low environmental impact; and,
- important socio-economical benefits.

5. Types of Priority Projcts

There are four main types of priority projects in Ecuador which have to be treated differently.

Group 1. Projects located in the border zone near Peru, a denselypopulated dry zone, with a deficit in hydroelectric potencial

This zone is known for its deficit in water and electricity. The situation is worse in Peru where there is even less water. The main challenge is to use the hydroelectric potential to the maximum.

Group 2. Projects in the priority border zone with Peru or the Amazonia. This is less densely populated zone with an excess of hydroelectric potential

The potential generally exceeds demand. In this zone, the most profitable projects, close to the populated zones to be developed (consumption for households or the development of local industry) or close to the current SNI or its planned extensions, should then be selected.

Group 3. Projects in the priority border zone with Colombia

This zone has an energy deficit although there is a very strong hydroelectric potential; rural electrification is developed, but the SNI is very often far away. Projects must be classified according to their profitability/feasibility and their social aspects. Special priority has to be given to zones near the Pacific in which waterways are the only access ways and where no SNI extension is planned, even though thermal generation is currently the sole source of electricity.

Group 4. Small projects located in priority zones with a strong social aspect; these are zones generally not connected to the SNI

These projects are often costly and require subsidies for construction. The tariff should cover only O&M, because of the low income of the inhabitants.

5.1 Barriers to small hydro development

Although there is such a tremendous potential for energy generation from small hydro, there are a number of serious barriers limiting its development, even though it is a pref-

Table 4.2 – Energy consumption in 2000 and estimate for 2009

Clients	Consumption in 2000		Consumption in 2009		Increase in Consumption
	(GWh)	(%)	(GWh)	(%)	in % /year
Residential	3421	41	5977	36.9	6.4
Commercial	1395	26.7	2640	16.3	7.3
Industrial	2173	26	5334	33	10.5
Public lighting and other	1365	16.3	2228	13.8	5.6
TOTAL	8354	100	16179	100	7.6

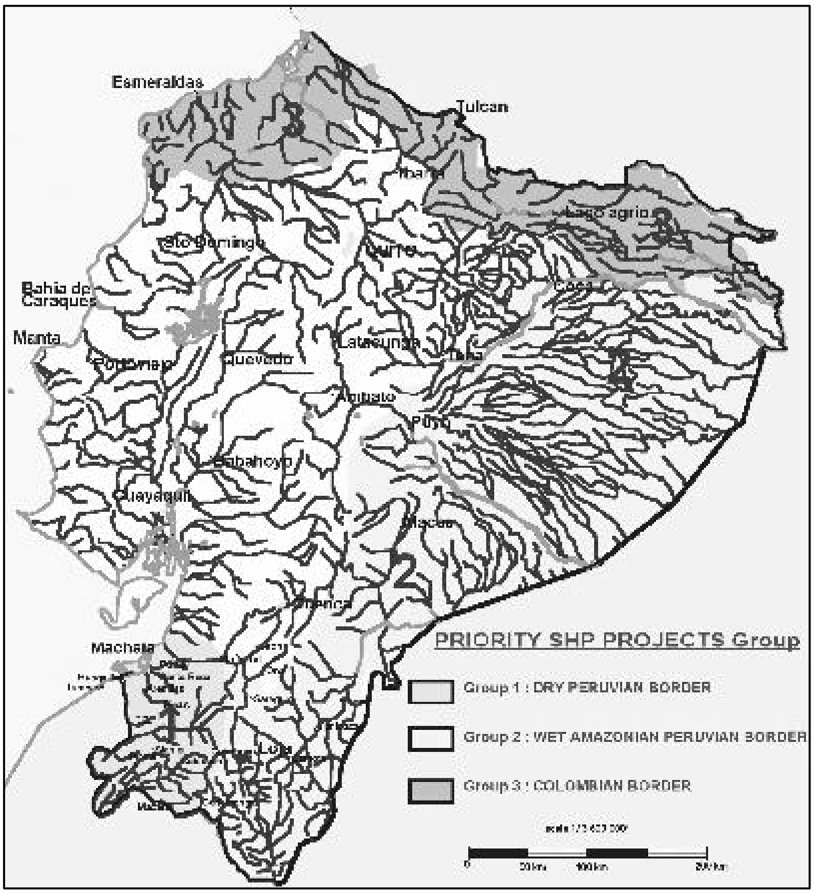
erable technology. Most of these barriers can only be removed by individual local governments, international organizations and bank programmes or the private financial sector. Until some of these problems are addressed, small hydropower will still show some major disadvantages compared with other technologies.

5.1.1 Financial barriers

- Lack of adequate capital at affordable cost: in 2001 the interest rates were about 20%.
- The financing of small hydro projects cannot be accomplished with one basic project financing strategy in the same way that many large scale conventional energy projects are often financed. Small projects vary considerably in scale, capacity, energy source characteristics, points of sale for output, status of technology and many other factors. Affordable financing is one of the critical factors inhibiting the use of small hydro.

5.1.2 Institutional barriers.

- An arguable choice of planning: Concerning the electrification of isolated off-grid villages, preference is often given by the institutions to connecting the line or to thermal diesel generation even though a hydroelectric resource exists and can be exploited at a much lower cost. A thermal diesel generator is cheap and readily available, but then has high maintenance costs; also the prices of fuel are volatile and there are environmental impacts. On the other hand, the environmentally-friendly small hydro alternative requires a large investment but the running costs are much lower and more predictable. In the case of grid connection, it is chosen to support the high cost of a long connecting line, as well as the waste of energy caused by line losses, the cost of which can be charged on the kWh. All this is because a lack of skills in the management of hydroelectric stations and of the local grid in these isolated regions is feared by decision-makers.
- Regulatory uncertainty: Ecuador has taken aggressive policy stances towards liberalization of electricity. Laws, policies and regulations have been put together which would seem to encourage the development of renewable energy and thus hydropower. However, the rules may be modified, or simply be adjourned, as a result of some other Government priorities. Since hydropower has a long-term development cycle, such uncertainty is a major obstacle to an investment decision by any private capital group. Consistency and long-term commitment to serious policies and direction are clearly identified.
- Policy obstacles to real least cost pricing: Lack of a standard small hydro power purchase agreement (SPPA) perfected in consultation with the electricity distributors. An SPPA would set up the rules for auto producers' sale of electricity to the grid, on the basis of a small hydropower purchase tariff (SPPT) chart. The SPPT sets a minimum level of price to pay to the producers, usually expected annual short-run avoided cost of energy not generated (often the running cost of thermal plant), giving tariff calculations and tariff periodic revision rules.



5.1.3 Technical barriers

- The technology is developed and continual improvements are being made in cost effectiveness: because there is no domestic industry specializing in this emerging sector, most of the equipment is imported. Consequently the costs are still very high. There is a lack of large scale production facilities, with the ability to work with the standards adopted for small hydro. Also, the equipment imported from North America or Europe is designed according to costly 'exports standards' or demanding manufacturing standards (used in the countries of origin and exceeding the requirements of small hydro in Ecuador). Some experiments have shown that the prices could be reduced to a third by designing simpler machines which could be made locally through local workshops.

- Data problems: the data requirements for renewable energy projects are very site-specific, requiring a detailed analysis of the specific local conditions, and they are scarce in Ecuador. Moreover, there is no central information centre on renewable energy in the country, and so data are scattered in various locations. Long-term data series hardly exist.
- In addition to the data deficiency, there are no norms or simplified specific methods for topographic and hydrological studies, civil engineering works, electromechanical equipment, power distribution or retail studies.
- Technical skills, including the ability to compile conclusive data comparing energy technologies for equivalent energy services are limited.
- There is a lack of specific simplified design methods.
- The application of standards aimed at larger projects leads to higher preparatory costs and distorted results.

5.2 Favourable factors for small hydro

Apart from these barriers, Ecuador has a real hydropower culture initiated early and regularly pursued, with small hydro that was used for the supply of major cities up until the time of larger scale hydro and thermal plant construction in the 1970s.

There are many sites in the country where high quality resources exist. The grid extends over a wide area, reaching all major communities. The next step will be the electrification of isolated villages.

The country already has numerous hydro installations, which have temporarily been shut down because of technical problems or because they are simply no longer used.

There is a strong interest in small hydro in the public sector, notably with provincial organizations or local authorities. This interest has also manifested itself in the private sector, but for the time being, projects are only implemented when the risk associated with energy sales revenue is either zero or at least very low. This is the case for energy-consuming companies using their own production, and for some water boards which are selling the energy recovered from the excess pressures on their network.

Small hydro is a particularly suitable choice to meet Ecuador's energy requirements, as it avoids fossil fuel consumption, allows for a wide distribution of generating plants, and contributes to a decrease in the risk of power shortages.

With the liberalization now under way, the electricity market is well adapted to initiatives of decentralized production.

As a result of liberalization, the approval procedure for a development project is clearly defined. Furthermore, the administrative steps can be conducted quite rapidly in a supportive spirit, and without major bureaucratic obstacles.

The Government has a policy to support the development of renewable energies. There are local policies for solar, wind, geothermal and biomass projects, and these are on the way to being extended to small hydropower.

6. FUTURE ACTIVITIES

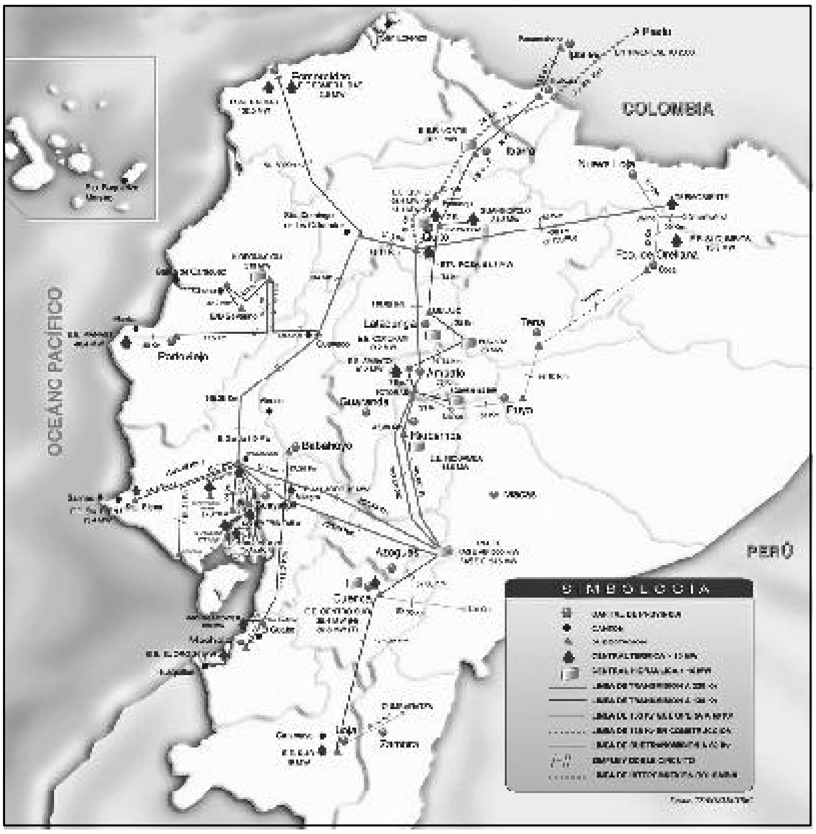
The Government of Ecuador (Department of Renewable Energies and Energy Efficiency, DEREE) has compiled a comprehensive programme to harness small hydro resources in remote areas and to develop and support the necessary private initiative. This programme aims at providing electricity and energy services to rural areas, to improve standards of living through income generation activities. This small hydro programme is expected to have a strong effect as an example, and attract private promoters to play a role in small hydropower development throughout the country.

The United Nations Industrial Development Organization (UNIDO) proposed an initiative, under the Global Environmental Facility (GEF), which will:

- Establish "social small hydro schemes" mainly not connected to the national grid, to provide electricity and energy services to rural households, enterprises and communities that cannot be reached economically by the national grid.
- Link renewable electricity to income generation activities to accelerate rural industrial development.
- Encourage private sector investment in selected small/mini hydropower projects.

Table 5.1 – Inventoried small hydro schemes

Inventoried SHP	Number	Total MW	Total US$	US$/KW	Av. MW	Av. US$	GWh/year
Group 1 (dry Pervian border)	24	36.6	95.6	2933	1.53	4.53	
Group 2 (wet and Amazonian Peruvian border	44	95.4	87.9	2180	2.17	3.38	
Group 3 (Colombian border)	34	58.1	95.5	3005	1.71	3.98	
Group 4 (small social projects)	42	4.43	10.3	3429	0.11	0.37	
Group 5 (Other projects)	101	285.8	592.7	2525	2.83	7.9	
Grand total	245	480.4	882.1	2736	1.96	5.04	2900



- Strengthen the professional capacity in the field of renewable energy.

There is also the Power and Communications Sector Modernization and Rural Services Project (PROMEC) financed by the World Bank and GEF. The GEF-funded component has the global objective of promoting the private financing and management of projects to reduce greenhouse gas emissions, by removing barriers to the use of renewable energy technologies to extend electricity supply in rural areas and energy efficiency measures.

The sub-component "Development of a rural electrification plan and programme implementation support", primarily funded by GEF, is designed to:

- Provide a sound national plan and strategy for both grid and off-grid rural electrification developed with participation of the principal stakeholders.
- Develop a variety of implementation mechanisms and approaches to lay the basis for a sustainable electricity expansion programme.

The sub-component "Pilot Projects for decentralized off-grid electrification" is designed to demonstrate sustainable as well as replicable institutional mechanisms for project financial administration and project operation and maintenance, to demonstrate sound technical performance and reliability, to meet consumer expectations, and to provide socio-economic benefits to end users.

- Rural Dispersed Population Pilot: this pilot scheme will consist of a number of site specific demonstration projects in various areas, designed to test the feasibility and effectiveness of a moderate sized rural "concession" or concession-like approach, for the planning, installation, maintenance, financial administration and local replication/ expansion of primarily household off-grid electrification systems. Typically the projects are expected to involve dispersed solar, wind or small hydro installations, potentially including minigrids, supporting public services, households and productive end uses in medium to high potential zones.
- Public Sector Infrastructure Pilot: this pilot project will demonstrate the sustainability and technical feasibility of dispersed electrification in areas with a lower socio-economic capacity. Support will involve energy supply for public services, for example in health clinics, schools, community centres, and telecommunications, as well as very small home lighting systems. Selected community or ethnic organizations, NGOs or other development organizations, renewable energy technology suppliers or project developers, electric utilities, or others representing communities may be implementing entities. Installations are expected to involve dispersed solar, and/or wind or small hydro installations. ■

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9th International Training Course on Small Hydropower Development

February 10-22, 2004 at Roorkee, India

Energy makes substantial contribution to the well being and prosperity of our society. Fast depleting fossil fuel and their associated environment consequences made all of us concerned. This has resulted in developing eco-friendly renewable energy resources world over. Hydropower, a renewable energy source, with no emission into the atmosphere, can have significant impacts on the environment. But electricity generation through small hydropower (shp), one of the proven, reliable and cost effective renewable energy source, has gained appreciable attention by government by government of various countries since last decade owing to short gestation period, low investment & least environmental impacts.

In India, Ministry of Non-Conventional Energy Sources(MENS), Govt. of India has accorded priority for the development of shp and renewable energy. This development is open for private sector participation. It has taken several policy initiatives supported with fiscal incentives.

To exchange experience with the participants from developing and other countries related to SHP, Alternate Hydro Energy Centre (AHEC) is organizing an International training course on the various aspects of SHP. During the course, the course participants would be provided latest information on investigations, planning, design, selection of hydro-mechanical & electro-mechanical equipment, operation & maintenance, environmental, financial & social aspects of SHP.

The expenditure on course material, technical visits, boarding & lodging (on twin sharing non a/c room), local transport and visit during the course has been sponsored by Ministry of Non-Conventional Energy Sources (MENS), Govt. of India. The participants through their organization are to bear/arrange the international travel expenses from their home country to Delhi International airport and back.

For further information and registration, please contact or write to:

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HRC signed SHP equipment contract with Vietnam

In 22 and 23 Oct,a group of 4 members including the International Cooperation Chief of Vietnam Institute of Hydro Resource, Director of HPC and others conducted a detailed discussion with HRC on automation lab equipment purchase contract. The agreement was reached and the contract signed on the morning of 23 Oct. That automation lab is one of the items for SHP cooperation as jointly approved by the two science and technology ministries of China and Vietnam. The establishment of the lab will hopefully promote the wide application of SHP unmanned automation technology in Vietnam. ■

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

German guests visited HRC

In 1-2 Nov. HRC received three guests headed by Mr.Geerken from Bremen Overseas Research and Development of Germany. The guests were arranged by HRC to pay visits to Tangpu SHP Station and Tinghu Rubber Dam. Discussion between HRC and the guests was conducted with the focus on the following items of interest for potential cooperation: Micro hydro power and hydropower automatic controlling system. Quotations of related hydropower equipment were provided to the guests and future cooperative steps will likely follow. ■

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

International Training Course on

"Small Hydropower Development"

(February 10-22, 2004)

Registration Form

(May be used as format)

Affix Photo

Name : Surname ....

Middle name ....

First name ....

Title:Mr/Ms/Dr ....

Organisation: ....

Position: ....

Address: (Office) ....

....

....

City/Zip Code .... Country ....

Tel(Off): .... Residence ....

(with country and area code)

Fax: .... E-mail: ....

Address: (Residence) ....

....

Details of Passport: ....

Passport No: .... Date of Issue ....

Date of Expiry: .... Place of Issue ....

Date of Birth: ....

Diet restrictions: ....

Citizenship: ....

Date: .... Place: ....

Excursion: Yes/No ....

Sponsoring Organisation ....

Date Signature

Note: Please send the Registration form at the earliest and preferably by January 20, 2004. The participants from different countries and Organization will be given preference for admission to the course.