HRC's Annual Report for 2005 and the Working Plan for 2006

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

In 2005, the international cooperation on SHP by HRC has scored a great deal. Two International Training Workshops on Small Hydropower respectively for African countries (French) and Asia-Pacific countries (English), sponsored by Chinese Ministry of Commerce, were implemented with success. The international cooperation has been intensified with the successful exportation of the equipment to Sri Lanka, Turkey, Japan, Vietnam etc. Visits in and out have promoted the mutual understanding and further expanded the external influence of HRC.

I International SHP training workshop

1 SHP training workshop for African countries

The 2005 International Training Workshop on Small Hydropower for African countries was held from 2nd Sep. to 26th Sep. at HRC. Totally 24 participants from 13 countries (such as Morocco, Burundi, Mali, Mauritius, etc.) attended this training. This training workshop has the following features:

1) Keep advancing in spite of difficulties and unceasingly improve our work

It is a challenge to adopt French in conducting the SHP training workshop for French-speaking countries. Staffs of HRC Secretariat actively learn French in their spare time and try every way to organize it well. HRC has organized to translate various specialized teaching materials of the SHP, and have been striving to seek the teachers who can directly present in French. In this training, teaching rate in French reached 30%. The satisfactory interpretation by the specially invited foreign interpreter who is proficient in French, English and Chinese promoted the quality of the whole training workshop.

2) Discuss to cooperate

According to the call of the Chinese central government "Water sector needs going global" and the relevant document by the Ministry of Commerce, one of the purposes to conduct the technical training is to push forward the transfer and exportation of the hydropower technology and equipment to the developing countries. In order to achieve this goal, during the period of training workshop, a series of SHP technical-cooperation discussions were conducted respectively with the participants from Rwanda, Congo, Mail, Niger, Guinea, etc.. In these discussions, their demand and suggestions have been explored related to the SHP development in their own countries, and HRC expressed the willingness to participate in or provide the SHP technical assistance. Many participants offered their national future development plan on SHP to HRC for cooperative reference, and expressed that they would actively stimulate the cooperation between HRC and their home countries, disseminating China's SHP technology and experience. At present several cooperative agreements have already been reached.

2 SHP training workshop for Asia-Pacific Countries

The 2005 TCDC Training Workshop on SHP for Asia-Pacific Countries was held from 20 Oct. to 28 Nov. by HRC, and altogether 30 participants from around 16 Asia, Africa, Eastern Europe and Latin American countries attended the training. This training workshop has three features as follows:

1) More study tours were arranged, including the visits to Hangzhou Dalu Electric Equipment Co.Ltd.and Hangzhou Sanhe Electric-control Equipment Co.Ltd., both the fast developing and vigorous private enterprises in Zhejiang province, as well as the HRC Laboratory, etc.. After the visits, especially in the meeting on SHP international cooperation, many participants expressed their intension to order the governors, the turbines or the TC operators.

2) In the view of the specific conditions on SHP exploration in developing countries, we made corresponding adjustment to the teaching material and the curriculum in time, ensuring HRC's presentations more appropriate to the situation of developing countries. Meanwhile, due to the environment issues, the international society pays more and more attention to environment protection currently, so we offered a topic on "Environment vs Energy", which was highly appreciated by the participants and they were extremely active in inquiry and discussion on environmental protection issues. Considering that most participants were also interested in items related to SHP investment and financing, we specially arranged a topic on “SHP Financing”.

3) In order to meet the partici-

pants' demands to understand China more, we specially organized them to visit Zhejiang Gongshang University and to participate in the discussion with the graduate students and university students. At this discussion, the representatives from four continents were asked to talk about the different impression or feelings before coming to China and staying China for more than one month. What they felt surprised all those present. As before they came they thought China was a country without any freedom, laying an embargo on free speech about the religion and politics; the police were patrolling on the street everywhere, and the common people were living in the plight of lacking food and clothing. The participants indicated that after returning to their own countries they would tell their colleagues, relatives and friends what was the real China like. Then after listening to the introduction by the University and walking around the new campus, many participants inquired the entrance condition for international students with the strong interest. The quick development of this university left a deep impression to those participants who excitedly indicated several times that this double exchange was surely essential and they enjoyed the great benefit from it.

II Information exchange of international SHP

The book ***"Status Quo and Problems of Small Hydro Development in Asia Pacific Region"***, written by HRC, was completed and published in November 2005. The study scope of this book focuses on the developing countries of Asia-Pacific region, as well as some developed countries in the area. The main purposes of the report are to provide the comparatively overall, objective, foresighted and independent reference material with full and accurate content for the decision-making departments of SHP in our country; also to put forward the demands of some developing countries to international society from our country and other relevant countries, and to supply the support for conducting the international cooperation and exchange better; at the same time, to provide a comprehensive research material about the world SHP for the international society.

HRC has arranged the translation and publication of many books, such as ***"Research on European Small Hydropower"***, ***"The Third World Water Forum Thesis Collection"*** and so on.

As invited by Chinese Ministry of Water Resources, Acting Secretary General of HRC Secretariat Mr.Pan presented a brief introduction of SHP in China to Rwandan ambassador in Beijing in June 2005. Friendly discussion was followed by both sides on SHP cooperation and other related issues of mutual concern.

In 2005, invited by the organizations such as ESCAP, our center dispatched two groups of people to participate in the international seminars and make the conference presentations. See table 1.

III International SHP Cooperation

In 2005, HRC dispatched experts to participate in the Asian Development Bank Gansu project of "Renewable Energy Sources Technology Aid". At present, this project is be-

Table 1 Participate in the international seminars/conferences in 2005

No.	The names of seminars	Time	Place	Host side	Participants	Remarks
1	East Asia "Modern Energy Services and Poverty Reduction" high-level regional workshop	May 4 - 6, 2005	Phnom Penh	World Bank, Global Village Energy Partnership （GVEP） and UNDP	Ms. Cheng Xialei	Nearly 180 delegates attended this meeting, and deputy director of HRC, Ms. Cheng delivered a special presentation.
2	Management of Hydro Power Development 2005, Advanced International Training Programme	Sep. 18- Oct. 7 2005	Stockholm	SwedPower International AB	Mr. Zhao Jianda	27 participants from 18 countries

ing carried out.

In 2005, HRC cooperated with IT Power of U.K to carry on the development of SHP Clean Development Mechanism（CDM）project. Now, three projects have begun to be compiled the project development document (PDD) and made the agreement negotiation of reduction purchase in Hunan and Hainan.

In 2005, through the support by the Ministry of Water Resources "948"project, HRC made the cooperation with Australia TYCO FLOW CONTROL TAMAR CO. to import the technology of containerized SHP station to fill in domestic gaps in this field. Then after owned by the state, the technology will have a good market prospect.

Aided by the Chinese government in 2005, the equipment complement for two SHP stations in Cuba, and the operation training workshop with duration of nearly 40 days for five skilled staff dispatched by the Cuban side have ended in satisfactory ways.

2005 is a year in which we have opened up some new path for further development. Promoting the exportation of electro-mechanical equipment is always the one of HRC's missions, but over the years the real achievement has been scored a little. In 2005，through the efforts from different divisions, many export projects of electromechanical equipment have been completed to several countries (such as Sri Lanka, Japan, Vietnam, Turkey, etc.). Meanwhile, the SHP automatic technology and equipment, self-developed by our center, have been pushed toward the international market.

In the first half year of 2005，our center has successfully completed the SHP consultation project to Rwanda, laying a foundation for the further bilateral cooperation. Our center also actively launches the technical cooperation with Australia, Pakistan, Indonesia, India, Vietnam, Korea, etc., and is always striving to contract, promote or implement the cooperation projects.

IV Visiting abroad and reception of foreign guests

1. In 2005, there have been total 7 groups of delegations sent abroad with 16 people succeeded in the declaration, including Rwandan, Mongolian (twice), Cambodian, Indian, Swedish delegations and so on, and relevant foreign projects have been guaranteed to smoothly carry out.（See the following table2）

Table 2 HRC's missions abroad in 2005（altogether 7 groups with 16 people）

NO.	Time	Number of people	Visiting countries	Visiting assignment and achievement
1	March 13th－22nd	4	Australia	The main purpose of this visit was to implement the project of "Key technical research on containerized SHP station". After field visiting and getting to know more about the local manufacturing situation of the packaged SHP station, a foundation was laid for the future application and popularization in China.
2	May 4th-6th	1	Cambodia	Ms. Cheng, deputy director of HRC, participated in the "Energy-Poverty Workshop", and delivered a presentation, which aroused the keen interest of all and launched a heated discussion. During the period of the meeting, the HRC expert also had conversations with the delegates from various countries and some international organizations as well. More potential international cooperation was expected.
3	May 10th–22nd	4	Rwanda	The 10-day technical consultation on SHP and water planning produced a marked effect. The technical support for SHP development and the complete set of SHP training scheme supplied to the Rwandan Ministry of Energy have received warm welcome and high appraisal, laying a solid foundation for further cooperation.

NO.	Time	Number of people	Visiting countries	Visiting assignment and achievement
4	June 22nd–July 1st	3	Mongolia	The HRC experts participated the technical coordination meeting of Taishir Hydropower Station in Mongolia. At the meeting, items on configuration, arrangement and installation of penstock, intake gate, main equipment and auxiliaries, oil-gas-water auxiliary system, primary and secondary electrical equipment, etc. have been discussed in detail. According to the suggestion of HRC experts and based on the characteristic of the Chinese electromechanical equipment, the original design has been optimized and adjusted, and finally a summary of the meeting was formed.
5	July 7th– 12th	1	India	At the invitation of Bengal National Chamber of Commerce & Industry, the issues on local SHP exploitation have been discussed. With more understanding to the situation of the country as well as its SHP development, a foundation was laid for entering the Indian market in the next step.
6	Aug. 30th–Sep.8th	2	Mongolia	Technical field service was supplied for Taishir hydropower station. The HRC experts have made technical coordination with the owner and the construction unit, and also have shared the views with the installation unit on the key technical problems concerned. Meanwhile, the work in next stage has been discussed with the related technical problems clarified. A finial summary of the meeting was formed.
7	Sep. 18th – Oct. 7th	1	Sweden	The delegate of HRC participated in the "Management of Hydro Power Development 2005, Advanced International Training Programme" with good result. During the period of training, the delegate of HRC also had technical exchange widely with the participants from various countries, and the achievements of the hydropower development made in China (especially in the aspect of SHP construction) were well popularized.

2. In 2005, altogether 16 groups of foreign delegations with more than 100 people have been accorded the cordial receptions by our center (the participants of the international training workshops included), including the water-and-electricity experts or technicians from the World Bank, Sudan, India, South Africa, Indonesia, Japan, Pakistan, Germany, Chile, Thailand, etc. and more than twenty ***2005 International Water Science Summer Campers*** from 13 countries. The visits of the foreign guests, on the one hand promoted the mutual understanding, on the other hand expanded the influence and raised the international standing of our center, powerfully impelling the international cooperation. (See the following table 3)

V Working plan in 2006

In 2006, the staff in HRC will redouble its efforts, striving for climbing up a new step in the aspect of the SHP international cooperation. Determined to do the following well:

1. To apply and conduct well the two 2006 international SHP training workshops sponsored by Chinese Ministry of Commerce. At the conference to celebrate the 60th anniversary of the founding of the UN, China's President Hu Jingtao announced that this country must en-

large the long-term scope of human resources development to African countries, and also indicated that this country would offer the training workshops for about 30,000 African participants in three years. We will implement the international training workshops better and adopt the measures duly according to the demands and suggestions proposed by the participants.

2. To strengthen the relation with the relevant international organizations from which we will try to have fund for running more international SHP training workshops to meet the demand.

3. To complete the work of constructing two SHP stations in Cuba sponsored by Chinese Ministry of Commerce and guarantee the electricity generation on time.

4. To continue to do the SHP follow-up cooperation well with Vietnam, Cuba , Mongolia, Rwanda, Australia and etc.

5. To further promote the substantive international SHP cooperation and develop the SHP engineering cooperation with Turkey, India and African countries. To strive to make the export volume of electromechanical equipment increase with a large scale on the basic of 2005.

6. To make full use of Internet and open HRC'^s homepage in French version in due time.

7. To publish the book "Status Quo and Problems of Small Hydro Development in Asia Pacific Region" in english edition.

8. To dispatch more SHP professionals to participant in the international activities (such as attending SHP seminars, conferences or forums) to exchange SHP technology and experience, and to make the new contribution for promoting the global SHP development. ■

Table 3 Guests hosted by HRC in 2005（altogether 16 batches with 100 people）

No.	Time	Country /Organization	Number of visitors	Visit purpose and achievement
1	January	Sudanese expert from the Ministry of Electricity	1	The close and friendly discussions were held between the two sides, focusing on the SHP development in Sudan, inclusive of the technical cooperation and training. A memorandum of Understanding for Small Hydropower Development in Sudan was signed in HRC. During his stay in Hangzhou, Dr. Hassan also paid visits to some of the SHP stations designed by HRC.
2	January	Indian expert	1	Indian electric engineer Ms. Sumitha paid a visit to HRC, and was introduced about the SHP business HRC undertakes. The two sides conducted a talk to explore the potential of cooperation in SHP automation, training, etc
3	March	World Bank consultant	1	Mr. Hansen, a WB consultant for Mongolian Taishir hydropower project paid a visit to HRC. During this visit, related items on design of intake gate, penstock and powerhouse, etc. were discussed.
4	March	South African engineers	2	Two engineers from South Africa paid a visit to HRC, conducting a technical discussion with HRC specialists.
5	May	Indonesian guests (headed by general director) from PT. NEW RUHAAK CO.	3	Indonesian guests paid a visit to HRC and conducted a detailed discussion on bidding of the three power stations in Indonesia and the cooperation in other aspects with HRC. They hoped to import Chinese technology and equipment to lay a foundation for developing towards SHP market.
6	June	Deputy chief from Hydropower Promotion for China Market, Toshiba, Japanese	1	After listening to the introduction about the SHP development in China, Mr. Momose briefed Toshiba's investment in and cooperation with China, especially the products by TOSHIBA (Hangzhou). Both sides expected to cooperate for promoting the SHP exploitation in Asian market for mutual benefit.

No.	Time	Country /Organization	Number of visitors	Visit purpose and achievement
7	June	College students from many countries (such as United states etc.)	23	The college students enjoyed the picturesque sceneries of "the Paradise on Earth"—Hangzhou, tasted the spirit of Chinese deep and ancient culture, understood the long history of water conservancy in China, and visited the Dayu Mausoleum in Shaoxing and many SHP stations.
8	June	Technical advisor from Alternative Energy Development Board, Pakistan	1	Both sides exchanged ideas on micro & small hydropower development, and intended to further strengthen the cooperation in micro & small hydropower fields as to push forward the rural electrification program in Pakistan. Dr.S.M. Bhutta also visited the SHP New-tech Laboratory set up by HRC and showed an intense interest in HRC's new technical products such as SHP-applied TC operator, governor, automatic control system and micro hydropower generating units etc.
9	June	Director from Megapoint Co. in Korea	2	The Korean guests carried on a discussion with HRC on some concrete cooperative projects, and visited a siphon type power station located in Dai Mountain of Xin Chang and some manufactories of turbines and generators as well.
10	September	Participants from thirteen African countries	24	During this training workshop, lectures are combined with discussion and case study plus study tours. All the participants were well trained, and gained fruitful results.
11	Oct.	Technical advisor from Alternative Energy Development Board, Pakistan	1	Dr.S.M. Bhutta paid a visit to HRC again to introduce the progress of SHP development in Pakistan, and conduced a discussion on SHP international cooperation. He also visited in high spirits some manufactories in Xiaoshan and Yangzhou.
12	Oct.	Executive director and senior consultants from TEAM consulting cooperation in Thailand	4	The Thai guests visited HRC and some manufactories of hydropower equipment located in Xiaoshan and Linhai, Zhejiang Province. The twp sides conducted a discussion on SHP international cooperation. The Thai side intended to import hydroelectric equipment from China.
13	Oct.-Nov.	Participants from 16 countries	30	During this training workshop, lectures are combined with discussion and case study plus study tours. All the participants were well trained, and gained fruitful results.
14	Nov.	Senior advisors of Bremen Overseas Research and Development Association (BORDA) in Germany	4	After learning the situation and experience of SHP development in China, as well as the status of manufacture and supply on micro & pico hydropower equipment, Dr.Bernd Gutterer expressed the desire to strengthen cooperation with China in the field of SHP exploitation.
15	Nov.	The C.E.O.from LI CHIHON LEY BCC in Chile	1	Mr. Chihon hoped that HRC would offer small hydropower equipment and technological support to Chile. Another purpose for this visit was that University of Santiago expected to get assistance from HRC for the training of SHP engineers.
16	Nov.	General Manager of Nam Nhone Hydropower Company LTD. (NNHPC)	1	This visit promoted the mutual understanding and both sides promised to cooperate with each other for developing SHP in Laos.

A New Approach for SHP International Training

An International Training Workshop on Small Hydropower for African countries was held at Hangzhou Regional Center For Small Hydro Power (HRC) in 2-28 Sept 2005, as sponsored by Chinese Ministry of Commerce. Totally 24 participants attended this training workshop from 13 African countries (such as Morocco, Burundi, Mali, Rwanda, Mali, Niger, Mauritius and etc.).

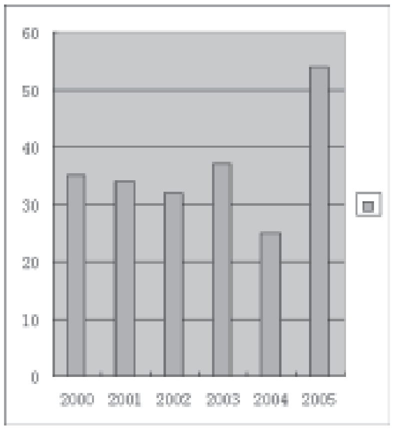
There are many African countries where French language is widely employed, including Algeria, Benin, Burundi, Cameroon, Central Africa, Chad, Congo, Cote d'Ivoire, D. R. Congo, Dogo, Gabon, Guinea, Madagascar, Mali, Mauritania, Morocco, Niger, Rwanda, Senegal, Tunisia and etc. As the SHP potential in those countries is huge but a large population has no access to electricity so far, there is a severe lacking of SHP technicians for SHP development. Mali participant introduced that the electricity coverage in the country is only 12% and in the rural area less than 1%. The situation in other countries is more or less similar. After visits to SHP stations and manufacturers in China, participants felt that SHP technology in China is proven, equipment reliable and price reasonable. Class monitor and the participant from Mali commented in his speech at the closing ceremony, "The small hydropower technology in China is just appropriate to the technical level of our Africa countries. HRC has strong expertise in SHP training, design, consultation and complete equipment supply. I sincerely hope that HRC will continue to hold the small hydropower training workshop to help the development of the SHP resources in African countries."

In the past, around 40 international SHP training workshops have been conducted by HRC and all conducted in English. Obviously there is an urgent need to conduct SHP training workshops in French so that the African francophones could benefit.

It is a challenge for HRC to adopt French in conducting this SHP training workshop for the African francophones, the first kind since the establishment of HRC in 1981. Staff of HRC Secretariat has actively learnt French since the time of the mission assigned by the Chinese Ministry to HRC and tried every way to organize it well. We have been striving to seek the teachers who can directly present in French. In the 2005 SHP Training Workshop for African Countries, around 25% of the teachers presented their lectures in French. The rest was presented in English through the interpretation by an African interpreter who was proficient in English, French and Chinese.

During the period of training workshop, a series of SHP technical-cooperation discussions have been conducted with the participants from Rwanda, Congo, RD Congo, Mali, Niger, Guinea, etc. In these discussions, their demand and suggestions have been explored related to the SHP development in their own countries, and HRC expressed the willingness to provide assistance to the SHP exploitation in these countries in terms of either SHP planning, training, designing or equipment supply. Many participants provided their national future development plan on SHP to HRC for cooperative reference, and expressed that they would push forward the cooperation between HRC and their home countries, disseminating China's SHP technology and experience.

The year 2005 of rooster according to China's lunar calendar was marked with harvest in relation to the international SHP training run by HRC, with the implementation of the International Training Workshop on Small Hydropower for African countries. The number of international participants increased dramatically as demonstrated in the bar diagram below:



Number of international participants increase by year since 2002 for HRC's SHP training workshops

2005 Training Workshop on SHP for Asia-Pacific countries implemented by HRC was also a success, as monitor, the Indian participant Mr. Yeptho pointed out at the closing ceremony, "We really appreciate and highly impressed not only for the fabulous facilities provided to us, but also for your sincere efforts to make all of us feel at home during our stay. The training program was definitely the world class with highly customized subject methods fitting each and every participant from different background. The training program was professionally managed with well balanced course materials, time distributions and other curricular activities."

Under the powerful support of Chinese Ministry of Water Resources, HRC upgraded its hotel and training facilities in 2004. Nearly all the participants of 2005 SHP training workshops were satisfied in terms of lodging and boarding.

For 2006 HRC is planning to conduct two international training workshops on SHP including one in French for participants from African countries. With its technical service and experience for decades, HRC is committed to participating in more SHP development for African countries and elsewhere in the world. The announcement for the SHP training workshops in 2006 will be issued at the first half of 2006 on HRC's home page. Those interested in the upcoming SHP training workshops may browse HRC's home page and are welcome to contact with us. ■

(By D.Pan, HRC training coordinator Email: dqpan@hrcshp.org)

Power Sale & Purchase Arrangement under Independent Power Producer (IPP) — SHP Projects funded by Indian Renewable Energy Development Agency Limited (IREDA)

The Independent Power Producer (IPP) generally have option to sale electricity to (i) state owned distribution company (Discoms) formerly known as State Electricity Board (SEB) before unbundling (ii) third party or a bulk consumer power intensive industry and (iii) Power Trading companies.

The Power Purchase Agreement (PPA) is entered between the IPP and the offtakers/power purchaser(s) based on the mutual agreed terms & conditions. However, the tariff for the electricity is governed by the broad terms and conditions of power tariff determination laid down by the Electricity Regulatory Commission of the concerned state (province) or Central Electricity Regulatory Commission.

The PPA is one of the most important documents for lender to decide the terms and conditions of loan and the risk mitigation. Apart from the credibility of the IPP or the stakeholders, the credibility & strength of the purchaser(s) also decides the degree of comfort level to lender while funding any IPP project.

The above arrangement is mainly entered between the seller & purchaser(s) or parties concerned, it is some time difficult to ascertain the transactions or in other words check the power sale proceed arrangement between two parties, particularly if they intend to divert the fund/revenue generated from the project. To keep a check on the cash flow of the IPP and mitigate the risk of recovery, tool for monitoring mechanism is introduce through third party bank called Trustee and Retention Account Banker. A tri-partite agreement is entered between the lender, IPP and Trustee Bank with detailed terms & conditions clearly stipulating the responsibility of each party. While it is a compulsion for the IPP as conditioned by lender to open separate special account called Trust and Retention Account(TRA), the trustee bank is a direct beneficiary by way of earning substantial amount as trustee bank services charges from the IPP apart from corporate account of power sale proceed. It is therefore an attractive proposition for any bank to provide the services of trustee bank under such arrangement.

Depending on the requirement of the lender for mitigating its risk, some of the important conditions generally covered under the TRA agreements are (i) right of receivables of designated accounts vests with lender (ii) Style and method of operation of various designated accounts under TRA as stipulated by lender (iii) conditions of advance instructions to IPP for depositing all the receivables including equity, investment income, revenue out of general compensations, insurance proceeds, damages under various agreement / contracts, loan disbursment etc. to the designated accounts (iv) irrevocable instructions by IPP to the offtaker(s) for remitting the power sale proceeds to TRA.(iv) appropriation of receivable credit in the various designated accounts under TRA conditions etc.

While there are various innovative mechanisms to keeping the check on the power sale proceeds under IPP power sale arrangement, the above arrangement is definitely one of the most effective tool for lenders. It also signals the lenders for any shortcoming of IPP or shortfall in the revenue due to any reasons, so that immediate measures are taken on time. ■

(By Kkekiho Yeptho G Dy. Manager ,IREDA,Core 4A, India Habitat Centre)

Hangzhou, Our Dream City Forever!

Time passed so quickly during the training in Hangzhou, which only covered a period of 40 days. However, to all the participants for the international training on SHP held in HRC, it was really a nice beautiful time, not only making them feel at home, but also giving them the happiest moment and the most unforgettable memories. Highly appreciating and deeply impressed by the real China and the picturesque city, the friends from various countries all over the world paid a charming compliment— Hangzhou, our dream city forever!

During the Chinese Spring Festival, far away from China, Mr. Yeptho, an official with Indian Renewable Energy Development Agency Ltd., was kept extremely busy, but he'd like to send the best wishes for a new year to all HRC staff and his friends in Hangzhou.

"Hangzhou, our dream city forever!" — Mr. Yeptho, the monitor of the class from India, together with the other 29 participants from other 15 countries, inclusive of Angola, Mexico, Belarus, Turkey, etc., came all the way to Hangzhou last year for attending 2005 International Training Course on Small Hydropower, held by Hangzhou Regional Center (Asia-Pacific) for Small Hydropower (HRC). However, so far, all of them have kept thinking fondly of Hangzhou. The stay of 40 days in Hangzhou, was "the happiest moment" and gave them "the most unforgettable memories".

"The training program was definitely the world class with highly customized subject methods fitting every participant from different background. The training program was professionally managed with well balanced course materials, time distributions and other curricular activities", Mr. Yeptho addressed at the closing ceremony on behalf of all the participants.

What Mr. Yeptho mentioned was true in fact. In order to make the training course more characteristic, HRC has spare no effort to well organize it. The perfect combination of theory and practice brought fruitful results to the participants.

During the period of studying in a "Paradise on Earth", the participants also enjoyed very much the experience for strolling in the city at their leisure time, appreciating the exotic scenery and getting to know more about the long history and the profound culture of the country. They never felt tired of sightseeing around the pretty West Lake and were always amazed at the picturesque sceneries, the green hills and the crystal serene waters. They also had a lot of fun to left happy footprints in ancient Qinghefang Street, Meijiawu Tea Village and the Silk Museum, etc. In addition, at the invitation of Mr. Zhao Jianda, one of HRC staff, some of the participants like Yeptho from India, Camilo from Ecuador, spent a delighting time in Mr. Zhao's house. On that day, they took dinner and had chats together with the Chinese family with great pleasure. Mr. Zhao also presented some pieces of the traditional "Chinese Knot" to the foreign friends as souvenir, in the center of which, the Chinese character "喜" (happiness) was of extreme interest to the visitors. Meanwhile, a detailed introduction on the marriage ceremony in China was thus made to the foreign friends who kept listening with rapture.

"All of us felt at home during our stay in Hangzhou" — in the closing ceremony of the training course, Mr. Yeptho spoke all his impression of Hangzhou in one breath:

It is a city of

— Happiness,
— Prosperity,
— Love and caring,
— Greeneries and flowers,
— Tea,
— Silk,
— Heritage,
— Good health,
— Young people,
— Romance,
— Pride and proud,
— Education,
— Business and Trading,
— Shopping ,
— Electronic,
— Culture,
— Joy,
— Ever young,
— Beautiful people.

and so on.

"In Hangzhou, we see with our own eyes a miniature of the real China", said the participants, "when we return to our countries, we will tell the realities and development of China to all the colleagues and relatives!" ■

(Translated from ***Hangzhou Daily of 7 Feb 2006****,* Written By D. Pan ,translated by X. Shen*)*

Flowing to the East — Small Hydro in Developing Countries

While the growth of small hydro has slowed in Europe, things look very different in Asia. The region accounts for two-thirds of the world's hydro capacity, and far from slowing down, it is enjoying robust growth. ***Simon Taylor, Drona Upadhyay*** *and* ***Maria Laguna*** *write this review.*

Access to electricity is one of the keys to economic development, as it provides light, heat, and power for productive uses and communication. Today, around 1.7 billion people in developing countries do not have access to electricity, most of them living in rural areas. Despite worldwide rural electrification programmes this number is increasing, largely because these schemes are not sufficient to cope with unsustainable population growth. Despite the fact that 80% of the world's population lives in developing countries, these countries consume only 20% of global commercial energy.

According to the World Bank, the world's poor people spend more than 12% of their total income on energy, more than four times what a middle-income family in the developed world spends. Achieving the United Nations' 'Millennium Development Goals', will require significantly expanded access to energy in developing countries.

China alone has more than half of the world's small hydro capacity and represents the bulk of installed capacity in developing countries

Accepting that energy is necessary, renewable energies must be used as a key tool in the contribution towards sustainable development in the less developed regions of the world. Small hydropower (SHP) is a renewable energy source which is suitable for rural electrification in developing countries. It is a proven technology that can be connected to the main grid, used as a stand-alone option or combined with irrigation systems. Thanks to its versatility it can significantly contribute to the electricity needs of the developing world.

The substitution of conventional sources of energy (traditional biomass for cooking, diesel generators, kerosene lamps and biomass stoves) with renewable energies like SHP can help decrease CO_2 emissions and also contribute to poverty alleviation and economic development by supplying electricity needs for lighting, water pumping and operating small workshops.

The emphasis of this article is on seeking sustainable markets for SHP in developing countries, with the implementation of schemes that consider sustainable development of the communities concerned and tapping into mechanisms that build a strong and long-term market for SHP in key developing countries. We take China as a case study as it is a country where there is currently a strong SHP market.

SHP IN THE DEVELOPING WORLD

Hydropower throughout the world currently provides 17% of our electricity from an installed capacity of some 730 GW, with another 100 GW currently under construction. This makes hydropower by far the most important renewable energy for electrical power production. In 2002 the contribution of SHP to the worldwide electrical capacity was on a similar scale to the other renewable energy sources (1%-2% of total capacity), amounting to about 47 GW. 25 GW (53%) of this capacity was in developing countries (Table 1).

TABLE 1. Installed SHP capacity by world region. Source: The International Journal on Hydropower and Dams, 2004; US DOE, 2004

Region	Installed SHP Capacity	Percentage
Asia	32,641	68.0%
Africa	228	0.5%
South America	1280	2.7%
North & Central America	2929	6.1%
Europe	10,723	22.3%
Australasia-Oceania	198	0.4%
TOTAL	**47,997**	**100%**

In the global SHP sector China is the major player, driven by long-standing rural electrification programmes from the government. 2005 figures, from the International Network on Small Hydropower, show SHP capacity has grown to 31,200 MW in 43,000 stations, meaning that China alone has more than half of the world's small hydro capacity and represents the bulk of installed capacity in developing countries. Growth in the Chinese SHP sector remains strong at 9% per year and there are plans to develop a further 10,000 MW in the next decade.

Other developing countries with significant SHP capacity are India (1694 MW), Brazil (859 MW), Peru (215 MW), Malaysia and Pakistan (both 107 MW), Bolivia (104 MW), Vietnam (70 MW), the DR Congo (65 MW), Sri Lanka (35 MW) and Papua New Guinea (20 MW), while Russia and the Central Asian states also have large amounts installed (totalling 639 MW)(2005 figures).

In the last 30 years China, Nepal, Vietnam and many South American countries have seen the development of a large number of micro- and pico-hydro projects which are providing electrification to many thousands of households. Chinese villages have developed the most micro-hydro, with 100,000 very small capacity units installed, amounting to 188.5 MW. Similarly, rural families in Vietnam have installed 130,000 pico-hydro systems (usually 200 Watts) in the last 15 years on a purely commercial basis. Yet although the cumulative capacity of such smaller hydro plants does not show up in the data, these projects are providing essential services to large numbers of populations in a wide range of countries and local topographies and conditions.

But despite these enormous efforts to improve energy services to rural populations through the extension of grids and the use of renewables such as SHP in the past thirty to forty years, the un-served population has not decreased significantly in absolute numbers - about 1.7 billion have yet to achieve any electrification. This amounts to roughly 400 million households,or 40% of the population of the developing countries, who remain a substantial market.

HOW SMALL IS SMALL HYDRO?

Although there is still no internationally agreed definition of ‘small’ hydro - the upper limit is usually taken as 10 MW (SHP definition supported by ESHA and the European Commission) although this rises to 25 MW and 50 MW respectively in India and China - in general SHP has minimal environmental impacts through the use of ‘run of river’ schemes.Also within the range of small hydro power, mini-hydro typically refers to schemes below 1 MW, micro-hydro below 100 kW and pico-hydro below 5 kW. Although all of these technologies could be regarded as small hydro power, they have specific technical characteristics that warrant their own definition. Generally speaking, micro- and pico-hydro technologies are used in developing countries to provide electricity to isolated communities where the electricity grid is not available, whereas mini-hydro tends to be grid connected. In most of the cases, no dam or reservoir storage is involved in pico-, microand mini-hydro schemes.

APPLICATIONS OF SHP IN DEVELOPING COUNTRIES

The World Energy Assessment estimates that between 1970 and 1990, rural electrification programmes reached about 800 million people. Most of the rural electrification programmes were achieved by extending grid connection, but a significant number of the projects in the developing world are provided by renewable energy (Table 2).

Of the electrification schemes using renewables, the majority involve SHP, largely because of its suitability for powering minigrids and deployment in remote, and often mountainous, areas. It has also been used widely for grid-based power generation, and has been a mainstay of rural energy development for many years.Village-scale minigrids can serve hundreds of households in settings where there are sufficiently clustered end-users. Most village-scale minigrids have been developed in Asia on the basis of small hydro, particularly in China,Nepal,India,Vietnam and Sri Lanka where they are often also powering small industries that provide substantial local income and jobs.

BENEFITS OF SHP

Using small hydro power for electrification in rural areas has many potential benefits.Apart from the environmental, health and social burdens of traditional fuels which are avoided by switching to electricity, direct economic benefits flow from the use of electricity in economically productive applications, such as irrigation, crop processing and food preservation. Employment opportunities have increased as a result of the encouragement of these productive applications and electrification has given increased potential for the development of business enterprises.

TABLE 2. Renewable energy markets and typical installations in developing countries. Source: Martinot 2003.

Application	Installations in developing countries market
Rural residential and community lighting, TV, radio and telephony	Over 50 million households served by small hydro village-scale minigrids
	10 million households with lighting from biogas
	Over 1.1 million households with solar PV home systems or solar lanterns
	10,000 households served by solar-wind-diesel hybrid minigrids
Rural small industry,agriculture, and other productive uses	Up to 1 million wind-driven water pumps and over 20,000 solar PV pumps
	Up to 60,000 small enterprises served by small hydro village-scale minigrids
	Thousands of communities with drinking water from solar PV-powered purifiers and pumps
Grid-based power generation	48,000 MW installed capacity producing 130,000 GWh/year (mostly small hydro and biomass, with some geothermal and wind)

In the past thirty to forty years, the un-served population has not decreased significantly in absolute numbers - about 1.7 billion have yet to achieve any electrification

For users who previously depended on traditional energy sources, the greater efficiency of electricity provides direct financial savings. At a national level, where electricity substitutes paraffin or diesel, it is also possible that there will be foreign exchange savings on imported fuel.

INVESTMENT PATTERNS

Renewable energy is currently undergoing a shift in investment patterns - moving away from traditional government and donor sources to greater reliance on private firms - meaning that it is now more important to think about markets for renewable energy rather than simply about the technologies themselves. The old technology-oriented paradigm focused on technology demonstrations and economic viability is being replaced by a new focus on market assessment, policy and institutional issues, and demonstrations of sustainable business models. Ongoing power sector restructuring in many developing countries is opening up competitive wholesale power markets and even encouraging self-generation by end-users using smaller-scale technologies.A growing share of the power generation field is being handed to private power developers and this is affecting the prospects (both positively and negatively) for grid-connected renewable energy, where SHP is or can be a major player.

These shifts are ones that new SHP developments have to consider. As well as the shift in investment patterns, changes in national policy are also important considerations for potential developers. Countries such as India and Brazil have policies to facilitate renewable power generation, such as 'wheeling' electricity to end-users via the utility's transmission lines, from which SHP is well placed to benefit. The SHP sector must also tap into local-level capabilities (as has been demonstrated in Nepal, the Philippines and Peru), involving the lower tiers of government, rural electric utilities, people's organizations, NGOs, small IPPs and most importantly, local sources of financing such as rural banks and credit co-operatives and even local entrepreneurs.

SHP POLICY FRAMEWORKS - THE CHINESE EXAMPLE

The development of good policy frameworks - for example, national policies for rural access to electricity including institutional, legal and financial frames;planning of target areas; capacity building for users and for local private sector; communication of the benefits for SHP as a sustainable tool for social and economic development - is key for the success of rural electrification by renewable sources.The history of SHP development in China is taken as an example of a number of economic and policy dimensions that have encouraged the rapid expansion of SHP technology, which could be emulated in other countries. The following three factors were found to be the major contributors.

Preferential government policies

The Chinese government has given numerous preferential policies and measures to encourage SHP development.These include tax reductions, soft loans and grants, the promotion of private firms to invest in SHP stations, and policies to protect supply areas and private property.

Indigenous manufacturing capability

Since the 1970s, when SHP in China saw huge growth rates of 20% per year and there was not enough manufacturing capability to develop the required 200 - 300 MW total installed capacity annually, the Chinese government mandated certain counties and provinces to develop their own SHP equipment and then continued to promote local manufacturing to reduce overall costs.Local industry was eventually able to manufacture equipment for a capacity addition of more than 3000 MW per year and today China is able to satisfy its domestic needs and exports hydro equipment to other countries.

Recognizing the advantages of small hydro power over large hydropower

China has long realized that SHP has benefits that cannot be achieved through large or mega hydro stations. For example SHP construction results in fewer environmental impacts and does not require the displacement of people. In addition, SHP technology is not complex and can be easily understood and transferred to a variety of communities. Since most SHP stations have their own supply areas and local grids, they can supply electricity to local people as well as connect to larger grids. This enables these stations to maximize profits by purchasing electricity from the large grid in times of low generation and sell it back when there is excess generation capacity.

ROUND-UP OF THE SITUATION IN CHINA

China has 17% of the earth's hydropower resource and has installed over half of the world's SHP capacity (31,200 MW).The total economically viable SHP resource is estimated to exceed 70,000 MW. 90% of the number of stations and 30% of this total capacity is in the mini-hydro and micro-hydro range (Table 3).

TABLE 3. China SHP stations by installed capacity (2001)

Type	Micro	Mini	Small	Total
Station number	18,944	19,609	4427	43,027
Percentage	44.0%	45.6%	10.4%	100.0%
Installed capacity (MW)	687	7171	18,404	26,262
Percentage	2.6%	27.3%	70.1%	100.0%
Annual output (GWh)	1860	20,245	65,036	87,141
Percentage	2.1%	23.2%	74.6%	100.0%

The use of small-scale hydropower to achieve rural electrification is a major characteristic of renewable energy development in China,and was begun in the 1950s with strong central government lead. At present, there are over 600 counties (accounting for 30% of all of China's counties) that rely mainly on small-scale hydropower for electricity (serving over 300 million people) and there is a programme for rolling this out to 400 more counties.

Since 2000, the rate of commissioning of new small hydro capacity has been increasing to an average of 2000 MW per year and posting healthy annual average growth of over 7%.The country has built up such an experience in SHP that it now has a strategy of 'going-out' to other developing countries to help develop projects (usually with Chinese technology).

Financing SHP

Each year, the Chinese Government invests •30 million in the development of small-scale hydropower, attracting additional substantial investments from local governments, enterprises, and individuals to the tune of a further •10 billion. However with declining government investment in the sector, other sources are often required to bring targeted projects to development, and the Clean Development Mechanism (CDM) is one avenue that Chinese developers are now considering. The financing of hydropower in China is currently stable.The 4 major Chinese (state) banks lend to hydro projects as they are considered low risk and their loan terms are usually 3 - 5 years and financing negotiations take only 3 months. Some companies already have credit ratings up to fixed amount of capital which enables them to borrow up to this ceiling in one month. Meanwhile small hydro power is attractive to commercial Chinese banks, which are very active in the sector. The Ministry for Water Resources also continues to provide low interest loans for SHP development,worth about RMB300 million (•29.9 million) per year.

THE CASE OF YUNNAN PROVINCE

Yunnan province in the southwest of China provides an example of an opportunity for foreign companies wanting to enter the Chinese SHP market. The province has abundant hydro power resources and an excellent track record of high annual operating hours for existing plants. The installed hydro capacity in Yunnan is currently 11, 710 MW, of which 2250 MW is SHP (19%). The economically exploitable hydropower resource is very large at 97.95 GW, however the percentage of hydropower exploited is still low at 7.5%. Yunnan's hydropower targets are 18,800 MW by 2010 and 62,000 MW by 2020 (although admittedly much of this is large hydro). This is in order to strengthen the grid in the south of China and transmit power from the west to load centres in Yunnan and for export to Guangdong, which has suffered power shortages in recent years. There is only one major manufacturer of SHP equipment in Yunnan, so equipment is imported from other provinces. For SHP projects less than 25 MW, approval is handled at prefecture level, making the project process fairly straight-forward.

New renewables policy

A new 'Renewable Energy Promotion Law'was approved by the National People's Council in February 2005 which set the target of 10% of the country's electricity generation being supplied by renewables by 2020. This is ambitious given that China's GDP may quadruple in the next 15 years, perhaps requiring the total grid installed capacity to perhaps have reached 1000 GW. Nevertheless, experts have suggested that 60,000 MW of SHP capacity be developed from the yet untapped small hydro resources and certainly, with the coming into force of this law at the beginning of this year, faster SHP development can be expected.

SHP industry

China has a wide range of domestic SHP turbine manufacturers (about 80 in total), as well as construction companies that specialize in SHP infrastructure, and these have been supported since the early 1960s to deliver the technology to the sector. However there is still scope for technology transfer to improve performance and bring quality up to European standards, and to introduce more advanced systems - particularly in the area of automated control.

In April 2003, the Ministry of Water Resources (MWR) released guidelines for the modernization of hydropower systems in rural China, which provide further direction and standards for small hydropower development. Its overall objective is to modernize 50% rural hydropower plants by 2010,and modernize 100% of the rural hydro sector by 2015.

CONCLUSIONS

Small hydro power has already proved itself as a major contributor to electrification in developing countries with over 50 million households and 60,000 small enterprises served by small hydro at the village-level, as well as by projects feeding power into grid networks. More than anywhere, China has integrated SHP into a large percentage of the country (1000 out of 2300 'counties') and hundreds of millions rely on minigrids powered by small hydro plants. India and Brazil have also been major players in SHP and many Asian countries now have many megawatts of plant installed.

Much of this activity has taken place with the involvement of European companies already, as the EU has long occupied a leading position in the world SHP market. But with a stagnation of development within the EU, there is a renewed emphasis for EU companies that offer SHP products and services to aim at emerging opportunities in new developing countries, and at a market that has shifted in terms of investment patterns (away from donor sources to greater reliance on private firms) and power sector restructuring that is opening up competitive power markets. The SHP sector players must also consider more local-level stakeholders and local sources of financing, as a main condition for success.

Overall, SHP can help in achieving the 'Millennium Development Goals', but there are key conditions that are needed in order to succeed in SHP electrification in developing countries:

- national institutional, legal and financial frameworks for rural electrification,
- willingness to identify target areas and define SHP electrification programmes,
- the strengthening of local technical capacities,
- the establishment of a high level of expertise in the local agencies of funding institutions,
- the expansion of support for local networking between stakeholders (rural developers, bankers, institutional and private sectors, etc.),
- the development of tools for local private sector development. ■

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Hydroelectric Power Capacity on the Rise

China's hydroelectric power capacity reached 115 million kilowatts at the end of 2005, reports the National Development and Reform Commission (NDRC).

Between 2000 and 2005, China increased its hydroelectric power capacity by 36 million kW with construction underway on a batch of major hydroelectric power stations and many other facilities starting operations.

The construction of the Three Gorges Project progressed well during the period and is expected to be completed in the new Five-Year Program period (2006-2010), according to the NDRC.

The development of substantial hydroelectric power projects capable of producing 70 million kW of power began during the five-year period, including some in west China as well as the major project linking the power-rich West to the energy-thirsty East.

To encourage the development of hydroelectric power, the Chinese government carried out a census of the country's water resources. It strengthened the preliminary work on hydroelectric power development and worked on designs for strategic projects.

To meet the rising energy demand of the country's booming economy, China is paying more and more attention to the development of renewable energies.

China promulgated a new law on renewable energy in February 2005. The law, which took effect from January 1, 2006, is considered to be of great significance to the development of China's renewable energy industry.

The medium *(Continued on P.18)*

Small Hydro Power Development in India — Private Sector Participation

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1 Introduction

India has a history of 100 years in small hydro power. However the country upon independence in 1947 has switched over to exploiting larger hydropower projects, and thermal power projects (mainly coal) to meet massive requirements of power. Of late since 1991, environment driven awareness over large hydro projects, and entry of private sector entrepreneurs into SHP Sector have given tremendous impetuous to SHP Sector growth in the last decade of 20th century.

Small Hydro is environmentally benign, operationally flexible, suitable for peaking support to the local grid as-well-as for stand alone applications in isolated remote areas. Even if we ignore the CO_2 abatement costs and 'acid rain' abatement costs of conventional thermal route, small hydro is benevolent on known hard facts of economics like short gestation and limited investments on small hydro are affordable by the private sector, enabling quicker electricity generation and economic returns.

2 Indian Potential of Small Hydro Power

India has one of the world's largest irrigation canal networks with numerous dams. It has monsoon fed, double monsoon fed as well as snow fed rivers and streams with perennial flows. An estimated potential of 15,000 MW of small hydro exists in India. The database created by Ministry of Non-Conventional Energy Sources (MNES) of Government of India includes 4,233 potential sites with an aggregate capacity of 10,324 MW. Out of this, about 1693 MW potential has already been tapped. Annually about 100 MW new capacity of SHP projects is added to the grid.

3 Small Hydro Development in India

The first small hydro project of 130 kW commissioned in the hills of Darjeeling in 1897 marked the development of hydro power in India. The Sivasamudram Project of 4500 kW was the next to come up in Mysore district of Karnataka in 1902 for supply of power to the Kolar Gold Mines at 25 Hz frequency. The pace of power development including hydro was rather tardy. The planned development of Hydro Projects in India was taken up in the post independence era (i.e. after 1947). This means that the 1362 MW capacity (including 508 MW hydro) installed in the country before independence was mainly coming from Small and Medium size projects.

4 Government Support to Small Hydro

Government of India, through its full-fledged Ministry of Non-Conventional Energy Sources (MNES) formed in the year 1992 - the year of Rio Summit on Environment and Development, is extending multi-dimensional support to the development of mini hydels (upto 25 MW) as one of the environmentally benign renewable energy technologies, keeping in tune with the Government's overall thrust on liberalisation of economy and private sector participation in power development. Fiscal incentives available for 'Small Hydro' sector are given in the follows:

FISCAL INCENTIVE FOR SMALL HYDRO SCHEMES

- Schemes involving capital up to Rs 1 Billion (i.e, Approx. US$ 22 million) need no Environmental Clearance from Ministry of Environment & Forests (MoE&F).
- Ten years Tax holiday on grid interactive power generation projects.
- Term loans through IREDA for schemes up to 25 MW.
- Customs duty exemption for Electro-mechanical Equipment (WB).
- Excise duty exemption for Electro-mechanical Equipment (WB).

ADDITIONAL INCENTIVES OFFERED BY MNES

- Promotional incentive Scheme to carry out Detailed Survey & Investigation (DSI) and preparation of Detailed Project Report (DPR).

· Subsidy scheme for setting up of commercial small hydropower projects especially in the private sector .

· Capital subsidy scheme for setting up of small hydro power projects in the State sector.

· Scheme for Renovation, Modernization and capacity uprating of small hydro power projects.

· Promotional incentive scheme for development and upgradation of water mills.

In addition to the above fiscal incentives, MNES has issued guidelines for off-take of power from renewables on concessional terms by the State Electricity Boards in respect of power wheeling, banking and buy-back. Several states of India have announced their Private Sector Policy, based on MNES guidelines.

5 Private Sector Participation

The States where small hydro potential is available have come out with attractive policies for private sector participation, in line with MNES guidelines. The pioneering efforts of the Karnataka State Government in establishing a Single Window Agency for clearance of SHP projects to private sector and the Karnataka Power Corporation (KPCL) as the nodal agency has sparked the growth of the sector and has become an example for other States to follow. Some of the success stories of private sector projects in the new era in the State are 18 MW. Shivapur project of Bhoruka Power Corporation, Bangalore and 1 MW Gokak Falls Scheme of Gokak Mills, Belgaum and 3.9 MW Shahpur Branch Canal project of Bhoruka Power Corporation, Bangalore and 2.8 MW Dhupdal Hydro Scheme of Gokak Mills, Belgaum. The neighbouring States like Kerala and Andhra Pradesh followed the example and many SHP sites were allotted to private sector companies mainly to meet their captive requirements. The first private sector project in Kerala namely, Maniyar 12 MW SHP, was completed in a record time of two years. The northern States of Himachal Pradesh, Punjab, Uttaranchal, and Uttar Pradesh, which have tremendous potential of hilly hydel schemes also announced their policies and their projects are under allotment / implementation for captive as well as power sale options.

6 World Bank Initiative through IREDA

A pre-investment study was carried out under the auspices of the Energy Sector Management Assistance Programme (ESMAP) jointly supported by UNDP and World Bank during 1989-1990 in association with the Indian Govt. agencies. The principal objective of this study was to apply techno-economic criteria to improve the design and economic viability of irrigation based mini-hydro schemes in India, and to identify and prepare a medium term investment programme to develop a series of irrigation based hydro schemes in India. This study covered more than fifty prospective small hydro sites in five states namely Punjab, Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu. Detailed techno-economic analysis and cost-effective designs were made for some of these sites.

Consequent to the ESMAP study, World Bank (WB) offered a line of credit worth US $ 70 million to be utilized during 1993-1997 with a target capacity sanction of 100 MW.

The credit line has moved fast enough and IREDA could sanction 47 projects with an aggregate capacity of 145.16 MW, exceeding the target one year ahead of schedule. The enthusiasm shown by the private promoters as well as their understanding that the small hydro is the most attractive long term option not only for their captive needs but also as a business opportunity by way of selling power at commercial rates have given a fillip to the sector and there is going to be a steady growth in the small hydro sector.

7 Second Line of Credit from the World Bank

Satisfied by the progress made in implementation of the first line of credit, the World Bank has extended an additional line of credit amounting to US $ 110 million to IREDA for development of 200 MW small hydro power capacity. Under this line of credits 51 number of SHP projects have been sanctioned, and many of them are under implementation stage, and some of them have been commissioned.

8 UNDP-GEF Initiative on Himalayan Small Hydro

Against the background of depleting forest resources of Himalayas, the UNDP-GEF India Hilly Hydel Project was initiated in the year 1994 as the first Indian Project from GEF portfolio in order to develop a national strategy and master plan for optimum utilization of small hydro resources of Himalayan and sub-Himalayan regions with an outlay of US $15 million. The scheme also envisages implementation of 20 demonstration schemes, upgradation of 100 water mills for electricity generation. A revolving fund of US $ 1.4 million has been created at IREDA to finance commercial schemes under the project. This initiative has created massive awareness amongst Private sector entrepreneurs to invest in hilly hydro SHP Project. As a result, currently there are several hilly hydro projects which are under implementation.

9 IREDA's Lending Activities

IREDA's Mission is to be a pioneering, participant friendly and competitive institution for financing and promoting self-sustaining investment in energy generation from renewable sources and energy efficiency for Sustainable Development.

IREDA's main objectives are:

- To promote Renewable Sources of Energy.
- To provide Financial support to Manufacturers and Users.
- Act as a Financial Intermediary.
- Assist in Rapid Commercialization.
- To Promote Energy Efficiency & Conservation, and
- To Provide Consultancy.

IREDA's mandate covers a wide spectrum of financing activities including the activities connected to energy conservation and energy efficiency. At present, IREDA's lending is mainly in the following areas:

- Hydro Energy
- Wind Energy
- Bio-Energy
- Solar Energy
- Developmental Activities / New Initiatives
- New & Emerging Technologies
- Energy Efficiency & Conservation

10 Emerging Scenario & Strategies for Future SHP Growth in India

From the foregoing discussions, it is apparent that in India, it is an opportune time that small hydro should get a strategic thrust, as environment driven awareness has rediscovered 'small hydro' as a principal renewable energy source for sustainable development.

For a multi-dimensional strategic thrust, identification of weak areas and threat perceptions need to be visualised carefully and appropriate steps need to be taken. In this connection, following is being addressed:

- Data Bank for hydrological data and pre-investment study reports of newly identified sites.
- Single window clearance facility in all the States.
- Uniformity of Wheeling & Banking facility.
- Uniformity of buy-back and third party sale.
- Uniformity in water royalty charged from Private Entrepreneurs.
- Consistent & conducive Government Policies.

11 Concluding Remarks

With the dawn of liberalisation policy in India, power sector is attracting private participation in a big way. A technically sound programme with entrepreneur's friendly environment conducive power policies are likely to spin off an entirely new techno commercial scenario paving the way for attractive business opportunities in Small Hydro Power sector. ■

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*(from P.15)*and long-term development projects for renewable energies designed by the NDRC and other related departments are expected to fulfill China's energy objectives up to 2020 and meet the government's emphasis on renewable energy.

Furthermore, the Chinese government has announced incentives in financing and taxation to encourage the development of renewable energies such as wind power, methane and bio-energy.

According to the NDRC, China's wind power has entered a large-scale development phase. By the end of 2005, China's wind power capacity had reached nearly two million kW.

Over the last five years, the Chinese government has set out a program for wind power development, which has laid firm foundations for China's wind power ambitions. China has also seen progress in the development and use of bio-energy, solar power and geothermal heat in the past five years.

At the end of 2005, nearly 17 million Chinese rural families were using methane and the number of major methane projects exceeded 2,000.

According to latest statistics, China's annual methane consumption has reached eight billion cubic meters. Experimental bio-power projects involving burning stalks have been started in North China's Hebei, Northeast China's Heilongjiang, and East China's Shandong and Jiangsu provinces.

By the end of 2005, the absorbable capacity of China's solar water heaters had reached 80 million square meters. The energy it produced is equivalent to burning 10 million tons of standard coal.

China's consumption of renewable energies in the year 2005 was equal to 160 million tons of standard coal, accounting for seven percent of the total energy consumption volume of the country, said the NDRC. ■ *(Xinhua)*

Environmentally Adapted Hydropower in Sweden

Björn Svensson, SwedPower AB, Sweden

Introduction

The alteration of watercourses has been extensive in Sweden as well as in other industrialised countries. Since the end of the last century the water table of about 2500 lakes have been lowered in order to reclaim farmland. More than 600 of these have been completely drained. This particular activity came to a halt at the end of the 1950s whereas the ditching of wetlands and dredging and channelisation of watercourses for the benefit of forestry are still ongoing activities. The regulation of rivers for the purpose of meeting differential needs of hydroelectric power commenced in the beginning of this century. At that time, the floating of timber constituted the economically most important profit from exploitation of northern Swedish rivers.

Freshwater once also contributed to a significant share of the food requirement of people, but this service has steadily declined. Today the per capita consumption of protein amounts to 90 g per day, of which 6% derives from fish. Less than 1 g is protein from freshwater fish or salmon caught or cultured at sea. Although the uncertainty regarding the contribution from recreational fishery is considerable, it is clear that harvesting of freshwater food resources is unessential for the sustenance of riparian settlements in Sweden nowadays. On the other hand, angling has turned out to be a strong advocate for maintaining free-flowing rivers and restoring the already harnessed ones. Together with ecologists, one seeks additional arguments for the redirection of using rivers to enhance sport fishery. Most of these arguments emanate from studies that demonstrate differences between aquatic and riparian biotic communities in regulated and non-regulated rivers, respectively. It might be that species protection and nature conservation will constitute strong arguments for modifying future reservoir operation in Sweden. However, recent experience points to the possibility of both improving environmental conditions and maintaining the power output. The purpose of this presentation is to provide the background information for such a way of reasoning based on the situation in Sweden. I will use fish to represent biodiversity and biological production because fish and fishery are often used as symbols for pristine and highly rated natural environments.

River Regulation in Sweden

Regulated Swedish rivers typically consist of one or a few major storage reservoirs followed by a series of river impoundments in the downstream direction. Power stations are either located in the dam itself or underground between the dam and the adjacent downstream impoundment (Fig. 1).

The major regulated rivers are generally fully harnessed between the uppermost dam and the sea, and consequently look like staircases when seen side-face (Fig. 2).

Large storage reservoirs are

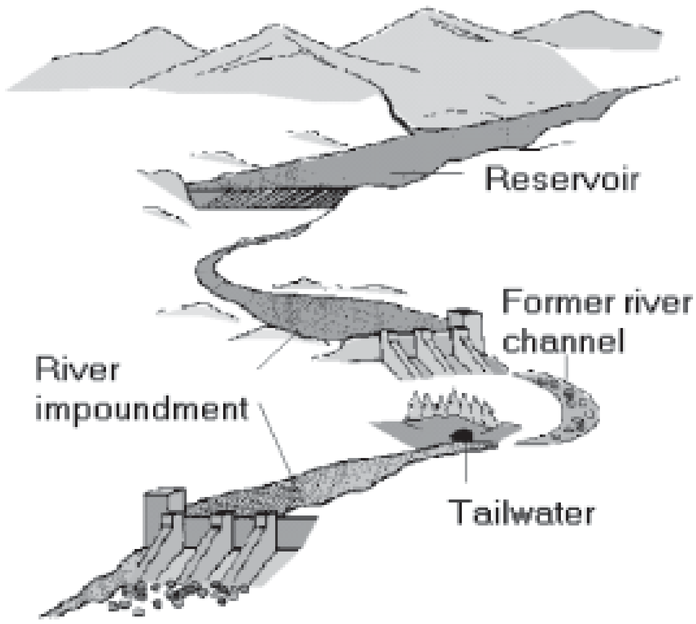

Figure 1. ***General outline of a large Swedish river used for hydropower generation.***

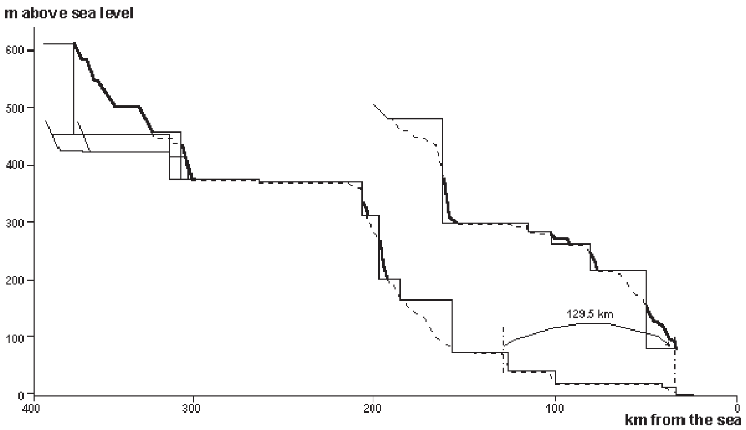

Figure 2. ***In the Luleälven river as well as in most other Swedish rivers, the total hydraulic head between the uppermost reservoir and the sea has been harnessed for hydroelectric purpose. This river consists of two main branches, i.e. Stora and Lilla Luleälven rivers (left and right profiles, respectively). Thick line denotes former river reaches below diversion points.***

mainly situated in the mountain ridge of northern Sweden. There, the annual specific runoff (precipitation minus evapotranspiration) exceeds 1000 mm as compared to less than 250 mm in the south-eastern part of the country. The natural seasonal variation in discharge also differs between different parts of the country, the hydrograph being comparatively smooth in the south and having a conspicuous spring peak caused by snowmelt in the north. This also means that the natural river flow in northern Sweden is more or less inversely related to the demand for electricity. Consequently, deviations from the natural hydrograph tend to be larger when northern Swedish rivers are regulated as compared to those at lower latitudes. In addition, hydroelectric power stations in southern Sweden are comparatively small and mainly of the run-of-river type.

As can be seen in Fig. 1, the regulated river mainly consists of three kinds of aquatic habitats:

(1) Reservoirs that are used to store water from the summer to the winter or sometimes even from years with high precipitation to comparatively dry years. The maximum water level fluctuation in a Swedish reservoir amounts to 35 m (Trängsel dam in the Dalälven river), whereas in natural lakes it is only about one meter. In the Luleälven river, which has the highest hydroelectricity generation in Sweden, the total length of the regulated branches is about 670 km of which reservoirs constitute approx. 146 km (covering a total area of 467 km^2 when completely filled).

(2) River impoundments are created between two adjacent dams and appendant power stations. The inlet to the impoundment constitutes the tailwater of an upstream power station. This reach is usually dredged or deepened in order to gain height of delivery. The other end of the impoundment is the dammed intake to the next power plant. Consequently, river impoundments are usually deeper than natural rivers. This also means that the available space for fish is larger in these impoundments compared to unregulated stretches. On the other hand, river impoundments are often used to store water for peaking power generation, which means that the water level fluctuates over the day and week (the amplitude is usually 1-2 m), thereby exerting a strong disturbance on the biota. In Luleälven, the total length of the impoundments amounts to about 430 km, at most covering an area of 500 km^2.

(3) River channels below diversion dams. Such reaches often used to be waterfalls or steep rapids. The water to the turbines goes through tunnels, and the former river channel is used as spillway only. Sometimes, a certain minimum flow is required, but often only locally generated runoff flows through the channel. In the Lulälven river, a total of 65 km belongs to this category. Two former rapids used to receive a certain minimum flow release, but the Water Rights Court (WRC), following a decade of evaluation of the possible benefits of this flow, later removed the requirements. One of the rapids, the 3-km-long Lullekjetjeforsen, has a bed material consisting of rocks and boulders in a wide and shallow channel. It would therefore be too costly (about SEK 0.3 $mill.m^{-3}.yr^{-1}$) to release a flow high enough to create a significant amount of habitats for brown trout *(Salmo trutta)* that once used to inhabit this part of the watershed. The other reach, Suorkejokká, is a 25 km-long-tributary to Luleälven. It is situated in the subarctic region. In the winter it is mostly dry or frozen, whereas in the summer it is fed by melting snow from the surrounding mountains, including one glacier. Following the diversion, the discharge decreased to about one tenth of the natural. An additional release of 2 $m^{3}\cdot s^{-1}$ from the reservoir during the winter had insignificant effects on fish production and only minor influences on ecologi-

cal processes so it was finally agreed to cut off this minimum release, which saved the equivalent of SEK 3.5 mill. annually.

The inundation of practically all main-stem spawning habitats of migratory sea trout *(S. trutta)* and Baltic salmon *(Salmo salar)* in the regulated Swedish rivers was accompanied by artificial rearing of these species in hatcheries and subsequent releases of smolts at the mouths of the actual rivers. Consequently, the maintenance of a base-flow to keep up natural populations of anadromous species is only meaningful in exceptional cases, i.e. where spawning grounds are still available downstream from the lowermost dam or in tributaries close to that dam. This is the case in, for example, the Dalälven and Umeälven rivers, respectively.

It is obvious that the potential for increasing the natural production of stream fish in the regulated part of Luleälven is rather small. The watered area at the highest water level is about 1000 km^2 as compared to about 600 km^2 before regulation of this river. Less than 10 km^2 of former riffle habitat is possible to restore at all unless the dams are removed or their function drastically altered. Given the anticipated low biological production in this nutrient-poor and cold river, it must be concluded that any increase in the release of water will probably be extremely expensive in relation to the additional fish yield it will generate.

Legislation

Legislation guiding the hydroelectric use of riverine resources is usually formulated to limit the potential impacts of the new constructions and their operation, and to handle competitive uses of these aquatic resources. Consequently, aspects of instream flow needs are influenced by two or more opposing needs. In a sense it is probably comparatively easy to handle questions related to instream flow needs if two similar uses in terms of economical benefits are competing for the same resource, since traditional economic methods can then be applied. It is much more difficult if one interest can be accurately quantified in economic terms while the others cannot. Such is the case in areas where either recreational fisheries or biodiversity issues are considered to be the main counterbalances to hydroelectricity generation. This situation nowadays applies to Sweden. However, when most of the regulation dams and power plants were built, competing economic interests were mainly considered.

Once a licence to build and operate a dam or hydroelectric power plant is issued, it is valid for all time. However, the conditions governing the project may be reviewed in accordance with certain regulations. Such a review means that the WRC determines whether there is cause to impose new or changed conditions for the project. The possibility of reviewing a license depends on what interests such a review should satisfy. Only conditions that are of common interest can be considered. The law identifies common fishery, environmental protection, human health, navigation and floating of timber as stakeholders. In practice, only the first two reasons are currently valid. Private owners who have experienced decreasing fishery yields as a result of a hydroelectric project are supposed to have been compensated (in the form of mitigation measures, complementary fishery opportunities, or economically) when review processes commence.

Applications to change the use of water are raised by a particular judicial body (Kammarkollegiet) who co-ordinates and pursues the future court process. This means that the two authorities responsible for fishery and nature conservation, viz. the National Board of Fisheries and the Environmental Protection Agency, are only indirectly addressed by the WRC.

As a result of the review process, the licence-holder must endure a maximal loss amounting to between one fifth and one twentieth of the total production without compensation. The WRC decided on the exact figure already when the licence was first given. However, the old Water Law maximised this loss to 5%. Since most licenses were issued at that time, deviations from the lower limit of the above range are rare.

Sweden has adopted a fairly comprehensive change of its environmental legislation. Although the potential losses of power generation as a result of review processes will probably remain the same, the final outcome of such processes may be altered in one important aspect in relation to the instream flow issue. Today, it is only possible to force a licence-holder to release water as a compensatory measure. Alternative means of achieving the same result, i.e. by undertaking so-called biotope adjustments or stocking of fish, must be paid by common funding. Since the latter kinds of measures are usually comparatively cheap, it has so far been common practice to make voluntary agreements between the power utility and other stakeholders, agreements that are later confirmed by the WRC. In the future, it will be a full reciprocity between different mitigative options in this respect, no matter whether these are entirely related to reservoir operation or alternative means of producing the same goods.

A Holistic Perspective

The average annual generation of hydroelectricity in Sweden amounts to about 65 TWh. This is roughly half of the total consumption of electricity in the country. A 5% reduction of the hydroelectric output as a hypothetical outcome of the review process just mentioned thus represents a rather significant amount of power as well as money, i. e. about SEK 0.5 billion annually. That is half the value of the current Swedish commercial fishery. However, since the most recent licences have already been considerate towards opposing interests by prescribing a certain minimum flow, the total possible loss will be smaller, perhaps 2 TWh at the most.

Since the hydraulic heads of diversion dams are comparatively high and the resulting dry river channels rather steep (Fig. 2), large amounts of water need to be released in order to reinstate fish habitats. The economic values that are then at stake constitute strong reasons for developing alternative methods that can improve fishery. Given the fact that Sweden has protected catchments corresponding to one third of the total land surface area against exploitation for hydroelectric purpose, it is reasonable to assume that increased discharges will only be reinforced to protect threatened and genetically distinct populations. It is doubtful whether this situation prevails in any of the regulated rivers today. Regulation has often resulted in a complete loss of local populations, and restorations *per se* of such fish stocks are of course no longer possible by any means. With respect to fish, the interest has previously been focused on the fishery yield, with conservational aspects being kept out of the planning. Mitigation measures have centred on strengthening the remaining populations or on introduction of breeds that have been considered to be better adapted to the altered environment. If such introductions have been at all successful, it is no longer possible to restore the original populations.

The fact that fishery rather than protection of the native fish populations has been the most important cause for concern facilitates the adoption of cost-benefit analyses. It also means that one can consider alternative means of producing the same goods. Hence, Swedish legislation now allows the replacement of fishery opportunities lost due to river regulation, by enhancing fisheries in nearby rivers or lakes. The economic benefits of such interchanges are obvious.

In recent years, instream flow needs in Sweden have been discussed in connection with the protection of biodiversity. It is usually stated that natural flow conditions are prerequisites for the maintenance of high richness of species. However, preliminary observations indicate that the macroinvertebrate fauna in dry, but temporarily flushed river channels, is similar to that found in the lowland riparian zone of free-flowing rivers. This zone is considered to be particularly sensitive to river regulation in Sweden. Consequently, dry river channels, although they are artificial structures in the landscape, constitute refuges for species that have become scarce or lost locally along harnessed watercourses.

Even if the sometimes strong demands in Sweden to increase instream flow releases also refer to general ecological amenities, the aesthetic aspects still appear to be the second most important argument for such claims. These aspects are also most difficult to describe in economic terms.

Something must also be mentioned about the costs of replacing hydroelectric power with other sources of electricity. Today and in the near future, shortage of domestic supply of electricity is covered by import from Denmark. Such electricity is generated in coal-fired power plants with little removal of acidifying substances. An average of 4% of the sulphur thus emitted is deposited in Sweden. There is enough knowledge to express the impact of this deposition in quantitative terms and to make comparisons with the impact of maintaining the hydroelectric output. Thus, in the particularly dry autumn in 1996, 3 TWh of electricity was imported from Denmark. The resulting sulphur emissions were large enough to exceed the critical load within an area that was larger than the total inundated area in the Luleälven river, i.e. 360 km^2 vs. 324 km^2, respectively.

Instream Flow

A number of methods have been developed in order to facilitate the optimisation of trade-offs between fish production and hydroelectric output. There seems to be three basic approaches that have been adopted so far.

The simplest methods are based on hydrological features and the assumption that there is a relationship between discharge and fish abundance. One anticipates that the size of a fish population is regulated by low flow rather than high flow conditions, and let instream flow needs equal the average low flow or a fraction thereof. The requested discharge is simply read off from the hydrograph or the duration curve. This or similar methods have been used in Switzerland, for example. The main objection to this method is that it does not consider the local topography. Although there might be a relationship between water flow and fish yield on a large scale, it is perhaps only valid as long as the natural proportion between flowing and still water reaches is maintained. Dams and power stations are often located in the steep reaches of rivers. Above such structures, a raised flow would naturally have led mainly to an increased water volume. In the regulated river this or an even larger volume is kept up by artificial means, so that alterations of the discharge will add very little to the available space for fish. In the rapid water, on the other hand, an increased discharge would naturally have added to the water velocity while providing about a constant water volume to fish. Consequently, since it is mostly the last-mentioned kind of river reaches that are considered when dimensioning instream flow needs, there is an obvious risk of sub-optimising the use of the water resource by applying this particular method. Other things being equal, for many species of fish an increase in water depth seems to influence population density more than an increase in water velocity does (Fig. 3).

The use of relationships between discharge and the wetted perimeter takes the topographical conditions into consideration. This method requires measurements of the shape of the river channel. In order to determine suitable instream flow levels with this method, one usually tries to find plateaus or inflections on the curves describing the above-mentioned relationship, i.e. levels above which additional amounts of water add comparatively little to the size of the water-covered area. A relationship of this kind, based on measurements of a large number of regulated and non-regulated river reaches, is given in Fig. 4. It has not been used in Sweden, but reasoning taking in the above-mentioned relationship is usually part of the decision-making processes. Unfortunately, it has proven difficult to establish relationships between the wetted perimeter and variables related to fish.

Since it is now possible to predict fairly accurately the hydrological features of river reaches by mathematical modelling, it seems possible to combine hydrological data and information on the habitat requirement of individual species in order to arrive at more accurate estimates of instream flows. As a matter of fact, that is what the frequently-adopted IFIM method aims at. Although this method has also been difficult to verify it satisfies the logic and repeatability required in juridical processes.

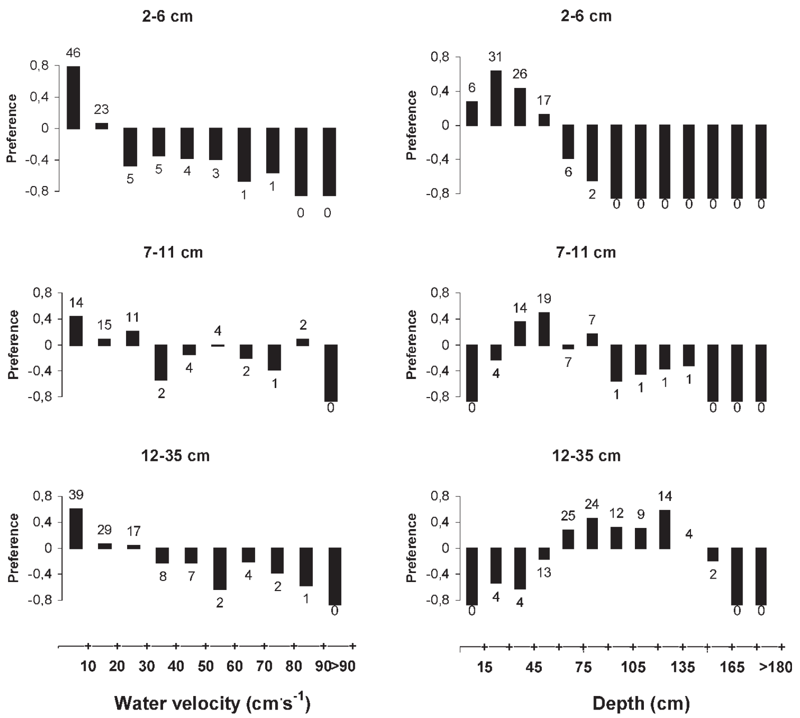

Figure 3. ***Daytime observations of preferences for water velocity and depth of different size categories of brown trout (Salmo trutta). Figures above or below bars denote number of observed individuals in each resource interval. Preferences calculated according to Jacobs' formula***

Biotope Adjustments

From what has just been described, one must conclude that discharge is one of several factors that influence fish productivity. Discharge consists of two components, viz. volume and rate. Provided the latter is of lesser importance than volume, it would be possible to achieve an increased fish production by manipulating volume only. This is brought about in the most cost-effective way by so-called biotope adjustments, i.e. artificial alterations of the channel morphology.

Biotope adjustments are often accepted as successful substitutes for increased releases of water in Sweden, both in connection with the issuing of new licenses and as outcomes of relicensing procedures. Since the water in the northern part

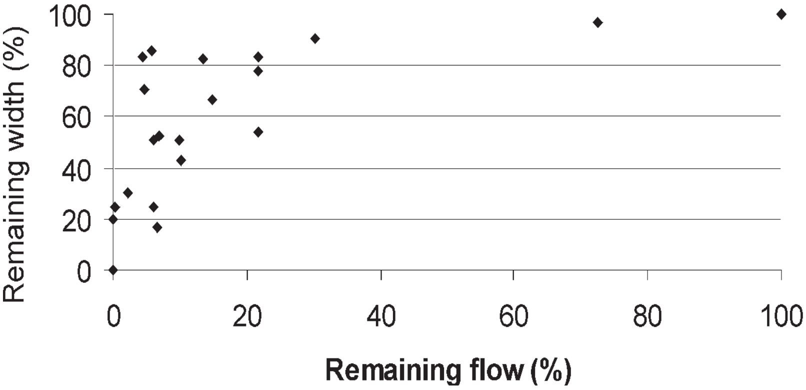

Figure 4. ***Relationship between remaining flow and width below some diversion dams in northern Sweden. Remaining flow is expressed as the percentage of mean unreduced flow.***

of the country is of good quality, flow reductions will normally not cause significant changes in the concentration of dissolved oxygen. Also, sediment transport is generally low, so that the generation of flush flows to remove silt from the spawning redds is rarely needed.

It is difficult to provide a general cost-benefit analysis of biotope adjustments. Based on the most recent projects, the costs of constructing weirs to raise the water table typically amounts to about SEK 7000 per m cross-section. Weirs nowadays consist of boulders and stones that are loosely arranged in order to give an impression of naturalness. Although occasional flooding might damage such structures, the natural appearance is highly appreciated. However, it is necessary to include cost estimates of future repairs even in the planning phase in this case. Costs for biotope adjustments that more broadly aims at enhancing the habitat for fish and other biota by diversifying the bottom topography and increasing the wetted perimeter vary considerably. Total amounts expended, including planning and field-working, range between SEK 15,000-50,000 SEK per km river reach.

Since biotope adjustments have long been established as common practice in Sweden, there has been little need to evaluate the outcome of such undertakings in scientifically satisfying ways. However, several of the more recent projects are now being studied in detail. Additional information on this matter also derives from Norway, where the effects of weir construction have been thoroughly documented.

Conclusions

River regulation creates artificial environments. Some of these environments are poor in terms of the number of species and productivity, but there seems to be good prospects of improving the situation in some of the impacted areas at least. In order to optimise the use of natural and economic resources, it is necessary to accept the fruitlessness of trying to combine generation of hydroelectricity and maintenance of pristine river ecosystems. The acceptance of hydropower as a legitimate resource use comparable with forestry and agriculture makes it possible to adopt a whole array of methods to improve its environmental performance.

Evaluations of different means of improving fishery in regulated rivers are difficult because it is not possible to close rivers or even reaches of rivers to fishery. Inter- and intraspecific interactions between fish have also turned out to be difficult to predict. Because vast amounts of money are at stake when dealing with instream flow issues, quantitative relationships between hydrological/topographical parameters and fish production are highly requested. For the sake of reciprocity it is advisable to accept methodological shortcomings for the time being, while continuing to improve these methods, rather than to untie the apparently loose coupling between hydrology and biology completely in favour of simply hydrological considerations.

Loss of power generation as a result of increased instream flows, is replaced by other means of generating electricity. Consequently, instream flow methodologies should be supplemented with methods that provide so-called full-chain-cost analyses of alternative electricity generation. ■

Office Building of SwedPower Internatonal AB in Stockholm

Mr.Zhao, Executive Editor-in-Chief of SHP NEWS visiting Mr.Björn Svensson at author's office in Sweden in Oct. 2005

Sediment Problem at Älvkarleby Power Station

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ABSTRACT

Älvkarleby hydropower station, with five old Francis and one new Kaplan turbines, draws water from the natural river through a 250-m long artificial headrace. Autumn 1995 a hole, caused obviously by sand abrasion, was discovered in the headcover of one Francis unit (G1), followed by new holes found in 1997 and 1998. Investigations are made, with the purpose of identifying the origin of the sediment and understanding its behavior in the headrace. Several locations along the river are examined through field observations, echo sounding and diving, aiming at locating the source of the sediment. This ends without definite conclusion, therefore whether the sediment transport will cease can not be answered. Assuming the sediment transport will continue, hydraulic model tests are made to examine the behavior of sand transport in the headrace. The results show that irrespective of how the old Francis units are operated, the sediment is transported along the right side of the old canal, not along the left as expected before the model was built. Strong bottom currents towards the Francis unit G1 carry sand with it, which accounts for the wear of its headcover. Efforts are now made to study potential measures for sediment removal from the headrace.

Älvkarleby Hydropower Station

Älvkarleby Power Station is located on the river Dalälven and is one of the three pioneer stations built by Vattenfall in early 1900s and still kept in operation. Figure 1 shows the bird's eye view of the scheme. The power station was put in operation in 1915 and comprises five identical units, denoted as G1 to G5 from left to right. It is of a design typical of that period, each having a horizontal shaft with two double Francis turbines and one generator. The nominal installed effect of each unit is 14.5 MW at a gross head of 22 m and a turbine discharge of 90 m^3/s. Figure 2 illustrates the typical cross-section through the units.

The power station was rebuilt and extended in 1988-1991. The original station was refurbished and a new Kaplan unit, denoted as G6, was added on the right side of the headrace canal. The installed effect is about 50 MW at a design turbine flow of 250 m^3/s. After the extension, the total discharge in the headrace increases from 450 to 700 m^3/s.

The water to the units is conveyed from the natural river course in a 250 m long headrace. The normal water stage in the headrace +22.5 m. In connection with the extension, the headrace was widened and a separate canal was excavated from the headrace to unit G6. The bottom of the old part of the headrace corresponds to +9 m, the new, extended part leading to unit G6 has a higher bottom elevation of +13 m and the transition between the old and new parts has an almost vertical face.

The canal is blasted out of rock and is enclosed by walls on the sides. The wall height has been determined by model tests to ensure that overflow will not occur in the event of emergency closure of the power station. The left canal wall was sealed and stabilized. The right wall, new in its entirety, is of concrete and founded on rock. A roadway bridge with one pier runs over the canal and is included in the general road system.

Headcover Abrasion of Francis Turbine

Autumn 1995 a hole was discovered in the turbine headcover of the Francis unit G1, situated at the very left of the old power station. The hole was repaired and the problem was considered as temporary. March 1997 saw a new hole in the same headcover, the diameter was about 15 mm. Another hole was found in November 1998. Figure 3 shows the damage of the headcover.

The new damages show that the wear of the headcover continues and the problem is not temporary. To find the reason to the damages and to take proper measures, investigations are made. The sand particles found in the canal have a diameter ranging from 1 to 10 mm; the majority falls within 1 - 3 mm, with a median of 2 mm.

The gap opening between the runner and the turbine housing (casing) is approximately 3 mm (Figure 4). The damages are contributed to

Figure 1: Älvkarleby hydropower station - a bird's eye view

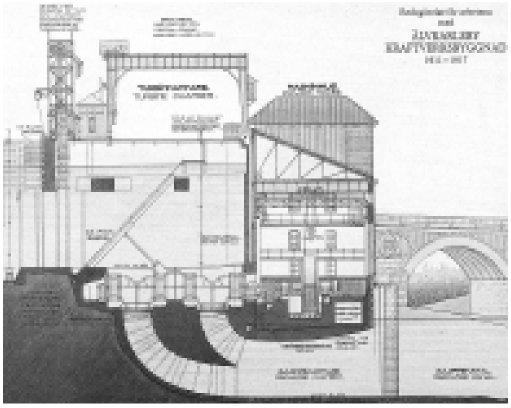

Figure 2: Typical cross-section through old Francis turbines

Figure 3: Damage in headcover of old Francis turbines

Figure 4: Sediment-laden water passes through the gap (3 mm) between runner and turbine casing

the sediment-laden water that comes through the gap with high velocity. Sand particles less than 3 mm pass through the gap and are found in water samples from the site. The entrapped sand particles rotate also with the runner and wear the headcover.

Abrasion caused by sand is also found in units G2-G5, but the damages are not as extensive and serious as in unit G1.

Sediment Transport and Handling Strategy

The power plant has been in satisfactory operation since 1915, without indication or experience of any problem with sediment. One question people naturally ask is that why sediment transport occurs now and whether it cease or not. The answer to this can be sought in two aspects - in the flow conditions and in the river bed.

Before the Kaplan unit (G6) was commissioned in 1991, the discharge in the river corresponded normally to the turbine flow, 450 m^3/s. The spillway was used only in excess of water. After the extension the river flow increases to 700 m^3/s. Due to this change, the sediment transport capacity of the flow in form of the bed shearing stress increases by about 140%, as it is a function of the square of the velocity. Such an increase might be enough to put in motion the sediment previously deposited in the river.

The headrace to the power plant is entirely blasted in rock and the sediment originates therefore in the natural course and not in the headrace. It is considered necessary to locate the sediment source. Where the sand comes and if it ceases to come govern the measures to be taken. If the sediment amount in the river is found limited, the best strategy might be to operate the power station as usual and repair the damage in the headcover in case of need. If the sediment source is endless and the sand will continue to be transported in the future, it is advisable to take engineering measures to remove the sand from the headrace and prevent it from entering the power station. Field investigations are necessary to locate the origin of the sand and to determine its amount.

Field Investigations along the River

The river Dalälven flows in Älvkarleby through an area with glaciofluvial origin characterised by material from fine sand to boulders. The river has through the years formed a stable riverbed with stones sizes adapted to the flow situation. Sediment problems have never before occurred in Älvkarleby power station since it started its operation in 1915 or in Lanforsen power station situated about three km upstream of Älvkarleby.

When the sediment problems started in 1990's two sources of the sediment was possible. Depending on the source different actions could be taken at the power station as described earlier in this paper.

The first possible source was a cofferdam that was built across the entire river during the refurbishment of the power station and dams. This cofferdam contained a lot of sand and some parts of this cofferdam were not removed. If the source was this cofferdam the supply of sand should stop after a while.

The second possible source of sand was from the riverbed from Lanforsen power station to Älvkarleby power station. During 1980's excavation took place in the riverbed to minimize the head losses from Lanforsen to Älvkarleby power station. The natural erosion protection was damaged and never restored. If the source of sediment was from the riverbed the supply could be endless.

A dive investigation summer 1998 showed sandbanks in the riverbed upstream of the headrace canal intake.

In 1998 and 1999 two consecutive echo soundings were made of this area. The echo sounded area was upstream of and in front of one of the three spillway dams and exposed to high flows during spill. The echo sounded area was also mostly upstream of the former coffer dam.

The results from the echo sounding showed that the bottom topography changed and the change was also upstream of the cofferdam. The net sediment inflow volume of the 5100 m^2 echo sounded area was 1748 m^3 or an average of 0.34 m sand. The only possible conclusion is that the sediment source must be upstream of the former cofferdam and we can not expect the sediment transport to stop.

Sediment samples were taken from different parts along the river and compared to the sediment found in the turbine. No conclusive evidence can be found from where the sediment originates. Assumptions are therefore made that sand will continue to come and measures must be taken, so that the plant can operate normally.

Laboratory Studies - Fixed-Bed Sediment Model

Hydraulic model studies were made at Vattenfall Utveckling AB, the purpose of which is to understand the behavior of sediment transport in the headrace and to provide a basis for suitable sediment control measures (Yang 2000). The model, in scale 1:50, consisted of the headrace between the natural river course to the power station. The model length was 12 m, the width was 3.6 m in the upper part and 2.4 m in the lower. The bridge pier was included in the model.

The model was used as a fixed-bed model, not as a movable bed one. Sediment particles were transported as bed-load, not as suspended load or wash load. Deposition of suspended load and re-suspension were neither investigated in the model. The model sand used was polypropylene. The particles were rather uniform and their shape was not exactly spherical. The diameter was on an average 3.8 mm. The sand density was 1075 kg/m^3.

The turbine discharge through each unit was calibrated and simulated accurately in the model. After trial and error and with the selected model sediment, the flow rate used in the model corresponded to about twice the Froude-number based flow rate. Sensitivity tests were also made so as to guarantee flow independent test results.

Unit G6 is a new Kaplan turbine with higher efficiency and in practice it is usually put in operation before other units. Different operation combinations of Francis units G1-G5 were therefore tested in the model to identify sediment pattern in the headrace. With unit G6 in operation, these combinations included 2 units, 3 units, shift from 3 to another 3 units, 4 units, shift from 4 to another 4 units, shift from 4 to 5 units and running of all 5 units. The following conclusions can be drawn from the model tests.

General sediment pattern — irrespective of how the five units are combined and run, the sediment is always transported along the right side of the old headrace (el. +9 m), not along the left side as expected before the model was built. The reason for this can be sought in the flow — the sediment follows the bottom current conditioned by the headrace geometry.

Change in operating conditions — when several Francis units are running with constant flow rate, a somewhat stable sediment pattern is usually obtained in the headrace. Closing one of them and at the same time putting another one into operation will immediately change the near-bed current in front of the power station and disrupt the already established stable sediment pattern. As a result, sand particles start to move into the units. The shift from G2+G3+G4+G5 to G1+G2+G3+G4 is a typical example.

To put one more unit into operation without closing any unit already running gives the same conclusion. An example can be the running of units G2+G3+G4+G5 with an addition of G1, corresponding to which the deposition pattern and sand particle movement in front of the units.

Sediment into unit G1 — when

units G1+G2+G3 are in operation (G4+G5 closed), about 90% of the sand is transported into unit G1 and almost no sand into unit G3. Another similar case is the shift from units G2+G3+G4 to G1+G2+G3. When a stable sediment pattern is obtained with G2+G3+G4 in operation, closing G4 and at the same time opening G1 leads to the fact that about 85% of the sand moves into G1.

Sediment into other units — with different running combinations, sand can be transported into other Francis units, G2 to G5. The amount into them is different and but it is usually much less than that into unit G1. No sediment is found in the new part of the headrace with a higher elevation (+13 m), meaning that the water conveyed to unit G6 does not contain any sand in bed load.

With the model tests, the sediment behavior in the headrace is identified and the sediment transport into the Francis units can be reasonably explained.

Field measurement of sediment pattern in headrace

To verify laboratory results, field measurement in the headrace was made after completion of the model tests. A x-y coordinate system was established for the headrace.

The sediment deposition pattern in the headrace from the diving agrees fairly well with what is found in the model. In other words, the model provides reliable results as to where the sediment deposits in the headrace.

There exists a stone trap immediately in front of the intake to the turbines. Dive inspection at another occasion shows that, in front of unit G1 and G2, the trap was full of sand up to the headrace bottom level, the amount of sand in front of G4 and G5 is however very limited. This confirms from another aspect the findings from in the model tests.

Sediment Removal from Headrace

To prevent the sand from being transported to the power station, it is not practical to take any control measures in the natural river course as it is wide. To stop the sediment somewhere in the headrace is considered as an advisable approach.

Downstream the new canal leading to unit G6, the velocity of the bottom current becomes lower. It is suitable to have a barrier on the bottom of the old part of the headrace and trap the sand. In the left wall of the headrace close to the power house, there exits an opening sealed by a safety valve. It is possible to have a self-suction system through this opening to remove the sand accumulated in the trap and discharge it to downstream the power station. This is however not dealt with herein due to the limit in paper length.

Conclusions

Following the discovery of the damages in the headcover of one Francis unit, caused by sand abrasion, field investigations were first made. The main purpose was to locate the source of the sand and to determine whether the sediment transport will cease or not. When the efforts to locate the sediment source failed, laboratory model studies were made, so that the sediment pattern in the headrace under different operation conditions and transport into the power plant can be explained. Efforts are now made to design the sediment removal system from the headrace.

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