ANNEX 1

SEMINAR PROGRAMME

Day One

Wednesday, October 26, 1994

INAUGURAL SESSION

0900-0945	Registration
0945-1000	Guests to be seated
1000-1005	Recitation from the Holy Quran
1005-1015	Welcome Address by *Mr. Shehryar Khan*, Chairman, Pakistan Council of Appropriate Technology
1015-1025	Introductory Address by *Dr. A.A. Junejo*, Project Coordinator, International Centre for Integrated Mountain Development, Nepal
1025-1035	Address by *Mr. Parvez Ahmad Butt*, Secretary, Ministry of Science & Technology
1035-1045	Address by *Sardar Talib Hasan*, Parliamentary Secretary for Science & Technology
1045-1055	Inaugural Address by *Mr. Muhammad Afzal Khan*, Federal Minister for Kashmir Affairs & Northern Affairs
1055-1130	Refreshments

SESSION I

1130-1230	*Mini- and Micro-Hydropower Development in Hindu Kush-Himalayan Region - Achievements, Impact and Future Prospects* Dr. A. A. Junejo, Project Coordinator, International Centre for Integrated Mountain Development, Nepal.
1230-1300	*Micro-Hydropower Programme of PCAT - Status Review*, Dr. M. Abdullah, Consultant on Micro Hydropower, Pakistan Council of Appropriate Technology, Peshawar.
1300-1430	Lunch

SESSION II

1430-1500 *Community Participation in Micro-Hydropower Development*, Ghulam Saeed, Regional Programme Engineer, Aga Khan Rural Support Programme, Gilgit

1500-1530 *Selection of Turbines for Micro-Hydropower Plants*, Samiullah Khattak, Assistant Director, MHP Project, Pakistan Council of Appropriate Technology, Peshawar

1530-1600 Tea

1600-1630 *Indigenous Development and Manufacturing of Very Low Head Micro-Hydel Power Plants*, Aftab Sarwar and Dr. S.M. Bhutta, Ministry of Water & Power, Islamabad

1630-1700 *Management of Micro-Hydropower Plants in Pakistan*, Dr. Habib Gul, Deputy Director, Pakistan Council of Appropriate Technology, Peshawar.

Day Two
Thursday, October 27, 1994

SESSION III

0930-1000 *Problems Associated with Decentralised Mini- and Micro-Hydropower Plants and Some Possible Redressals*, Dr. A. A. Junejo, Project Coordinator, International Centre for Integrated Mountain Development, Nepal.

1000-1020 Socioeconomic *Impact of Micro Hydropower Plants in the Northern Areas of Pakistan*, Ghulam Umar Sarhandi and Rauf Ahmed, Pakistan Council of Appropriate Technology, Islamabad.

1020-1040 *The Tyson Turbine - Another Remote Area Power Supply and Water Pumping System,* Fazal Rehmaan, Rashid A. Sheikh, and D. Singh (Imperial Electric Company Ltd., Lahore & Horwood Bagshaw Ltd., Australia).

1040-1100	*Mini -Hydropower Programme of Northern Areas' Public Works' Department,* Abdul Amir, NA-PWD, Gilgit
1100-1120	*Economic Feasibility of a Small Hydropower Station at Lower Bari Doab Canal, Mian Channu, District Khanewal,* Shaukat Khan and Wahaj us Siraj (Waterman Consulting Engineers & Ministry of Science & Technology)
1120-1145	Tea
1145-1300	Preparation of Conclusions by the Committee
1300-1430	Lunch

CONCLUDING SESSION

1430-1440	Presentation of Seminar Conclusions
1440-1530	Discussion
1530-1540	Remarks by the Participants
1540-1600	Concluding Remarks by the Chairman of the Session
1600-1630	Tea
1630	Closure

ANNEX 2

LIST OF PARTICIPANTS

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ANNEX 3

SUMMARY OF THE PAPERS PRESENTED AT THE SEMINAR

Summary

Micro-and Mini Hydropower Development in the Hindu Kush-Himalayan Region: Achievements, Impact, and Future Prospects

Dr. A. A. Junejo

Traditional water wheels for grain grinding purposes have been used in the Hindu Kush-Himalayan region for many centuries. The use and achievements of modern MMHP in various countries of the region; detailed analysis of the present status; and utilisation and future prospects of MMHP are discussed here. MMHP offers several advantages over the large hydropower systems and other sources of energy (thermal, biomass, and so on). MMHP is an indigenous and renewable source of energy, sizeable potential exists in the region; plants are more viable for remote and isolated communities; plants are easier to design and manufacture locally, and operation and maintenance costs of privately owned/operated plants are much lower.

Although the actual contribution to the energy requirements of mountain areas is still minimal,considerable progress has been made in the five countries of the region in terms of numbers of installations in the MMHP range. In India and Pakistan, the share of MMHP is less than one per cent of the total harnessed hydropower, whereas the proportion of the potential may be around 10 per cent. In China, the MMHP-SHP share in overall exploited hydropower is about 20 per cent.

In Bhutan, there are 19 MMHP plants, with a total capacity of 3.40 MW, all installed by the government under various aid agreements, mainly with India and Japan; this is apart from the three small and medium hydropower stations with a total generating capacity of 338.75 MW. Most of the equipment for the MMHP plants has been imported from India and Japan and installed by the foreign consultants. Likewise, much of the funding has been provided by foreign donor agencies. So far, the government has no plans to allow the private sector to participate in MMHP installations.

In India, there are 145 existing SHP/MMHP plants (up to 3 MW in capacity) having a total capacity of 106 MW, all installed by various government agencies, while 159 additional plants with a cumulative capacity of 198 MW are under construction. About 100 installed plants with a capacity of about 70 MW are located in the northern Himalayan region. Some NGOs have also began to install MHP plants in certain areas.

In Nepal, the number of plants installed by the government sector is 35 with an installed capacity of nine MW, out of which only five are grid connected. There are some other MMHP plants managed and operated by private non-commercial establishments. The largest number of MHP plants (over 700) have been installed by the private informal sector. Another interesting endeavour is the improvement of the traditional *ghatta* (water wheels) which are mainly used for grinding purposes and about 200 units have been improved by replacing the traditional wooden runner with one made of steel and improvising with buckets similar to turgo turbines. This almost doubles the efficiency of the mill with a small expenditure of US$100.

Most of the MHP plants were installed in Nepal during the eighties, when the government provided 50 to 80 per cent subsidy for electrical equipment, loans were made available for mechanical equipment and civil works, and licensing requirements for MMHP installations were removed. No comprehensive survey has yet been carried out to determine the status of operational and non-operational plants. There is, however, a general apprehension that many of the units are not in operation due to various reasons.

The manufacturing of MHP equipment in Nepal is quite advanced, particularly in view of the country's weak industrial infrastructure. The first manufacturer of MHP turbines in Nepal was established in 1960 with the technical assistance of the Swiss Government. The number of manufacturers has grown to 11 over a period of time. Most of these are involved in the manufacture of cross-flow or Pelton turbines.

The Chinese MMHP/SHP programme was initiated in the fifties. At present, Chinese MMHP/SHP installations (up to 25 MW in capacity) total 48,284 with a total generation capacity of 15,055 MW, and an annual energy generation of about 47 TWh. Out of the total installed plants, 45,645 plants are in the mini- and micro-range (up to 500 kW). About 35 per cent of the plants are grid connected, and form 93.5 per cent of the total power generated from MMHP/SHP plants. Most of these plants are installed on a decentralised basis by the respective local governments, and funding is provided by different public sector agencies.

Hydropower, including MMHP, development, in Pakistan is predominantly carried out by the public sector agencies. Two organisations, namely, the Pakistan Council of Appropriate Technology (PCAT), a government agency, and the Aga Khan Rural Support Programme (AKRSP), an NGO, are involved in the private MHP development. The plants installed by these organisations involve a subsidy component and are operated and managed by the local communities. PCAT has installed a total of 160 MHP plants with a total generating capacity exceeding two MW. These plants are based on the cross-flow turbines, and no electronic load controllers are used to regulate the power supply or load on the alternator.

AKRSP has installed 26 MMHP plants with a total installed capacity of 600 kW. Unlike PCAT, AKRSP has installed various types of turbines for their plants, including the cross-flow, propeller, Pelton, and Francis. As in the case of PCAT, all the electromechanical equipment is manufactured locally, except for the alternators. Costs of MHP plants installed by PCAT are between PRs 10,000-15,000 (US$ 330-500) per kW, whereas AKRSP's costs are PRs 9,000-15,000 (US$300-500) per kW.

In Pakistan and Nepal, the cross-flow turbine dominates all other types of turbines used in MHP plants, while Chinese MMHP/SHP plants are equipped with a range of turbine types, i.e., Francis, Propeller, Tubular, Turgo and Pelton. India also manufactures a variety of turbines with outputs of up to 3.0 MW. The alternators are mostly procured from China (in the case of Pakistan) and India (in the case of Nepal and Bhutan) in the region. Quality and performance problems associated with the MMHP equipment produced indigenously within the region are usually considerable. Failure of civil work has also been quite severe.

All the public sector plants installed by various government agencies are managed and operated by them in a centralised way, whereas in the case of privately-owned informal plants, the total operation, management, and maintenance responsibilities lie with the owners. In the case of community owned plants, the management is assigned to one or two persons by the village organisations.

All the five countries in the region have announced some level of support for MMHP development. In Nepal, for instance, policy support and incentives have been provided to the entrepreneurs for MHP development. These include provision of soft term loans and subsidies, de-licensing of MHP plants, encouragement to private sector (local as well as foreign). Both the Governments of India and Pakistan have also announced incentives for investors interested in MMHP-SHP installations for power generation. These policies and incentives, if implemented properly, would help the programmes significantly.

The end use of MMHP plants in the whole region is primarily for domestic supply of electricity, except in Nepal where a majority of private plants are used for agroprocessing and other similar activities. In all cases, the plant factors are quite low and range from 10 to 30 per cent. The major reasons for such low plant factors include negligible commercial or industrial utilisation of electricity and the poor purchasing power of recipients to use the electricity, for domestic appliances other than lighting. As the plant sizes grow, as is the case in China, the reliability and quality of electricity improves and leads to grid connections and industrial applications, resulting in considerable improvement in the plant factors. The enhancement and diversification of end uses would make MMHP installation more viable financially for private entrepreneurs. Some other possible end uses include domestic cooking and heating, commercial uses in shops and lodges, and cottage-level industrial applications.

The costs of MMHP plants per kW installed vary considerably within the region. In Pakistan, these costs are US$ 330-500, whereas in Nepal the costs range from US$ 800 to 2,000 per kW installed. Electrification schemes are more expensive than agroprocessing plants, mainly because of the additional costs of transmission and distribution lines. The tariff system of the informal MMHP plants is usually based on a per bulb or per point per month basis, except for a few plants in Pakistan where energy meters are being used for this purpose.

The impact of MMHP has been significant in the region. In China, where MMHP activities started about 40 years ago, more than one-third of the total counties rely on electricity generated by SHP/MMHP plants. Private MHP installations in Pakistan and Nepal have also made considerable progress. It can be safely concluded that, if some level of financial support is continued for MMHP, the overall energy scenario of the rural mountain areas in the HKH region can improve significantly. The emerging trends for future MMHP installations clearly suggest that electricity supply from MMHP plants needs to be improved qualitatively and made reliable in order to attract commercial and industrial consumers. Other steps include uses of electricity for lift irrigation, rural industries, domestic and commercial cooking, and grid connections and proper management of the plants, including implementation of novel electricity tariffs.

Summary

The Micro-Hydropower Programme of Pakistan Council of Appropriate Technology - An Overview

Dr. M. Abdullah

The Pakistan Council of Appropriate Technology has been active in development and distribution of renewable energy resources and their application, food processing technologies, sanitation and hygiene, and income-generating activities for about two decades. In accordance with the appropriate technology concept, indigenous, small-scale and low-cost appliances and processes are developed/adapted and then transferred to those who are in need of such technologies. Technologies are adapted to suit the techno-economic situation of the target group.

The mountainous regions of Pakistan have been blessed with a lot of hydropower potential. The recoverable potential is estimated to be nearly 21,000 MW, out of which only 4,725 MW have been exploited. Besides large hydropower schemes, there are a number of perennial smaller streams which can be successfully exploited for the supply of electricity through small decentralised MHP plants to isolated and scattered settlements where grid extension is economically unattractive and the villagers have to rely on kerosene and firewood for lighting and other domestic needs.

Keeping this situation in mind, the MHP programme of PCAT was started in 1975 when the first three kW plant was installed in Qadir Nagar, NWFP. Appreciating the success of the technology, PCAT decided to go ahead with the project and a second 12.5 kW plant was installed in Lilloni, Swat District, NWFP. Since then a total of 180 plants have been installed with an overall generating capacity of about 2,200 kW.

The main objectives of the programme are to promote the use of small water streams, a renewable source of energy, for power generation; to promote the use of locally-produced equipment for power generation, which contributes to self-reliance; to provide electricity to selected villages in selected areas; and to provide opportunities for enhancement of economic activities through installation of small industrial units.

The MHP programme of PCAT aims at benefitting the communities of remote and inaccessible areas, which are far away from the existing physical infrastructure, by disseminating simple and low-cost technology. Costs of MHP plants are site-specific and directly related to the capacity of plants and extent of distribution networks. Typical values, based on average conditions, are in the range of Rs 10,000-15,000 per kW installed. The cost/kWh delivered is estimated as Rs 1.55 and Rs 1.09 for 10 kW and 20 kW power plants respectively.

The MHP project of PCAT is funded by the Government of Pakistan under the Public Sector Development Programme through the Ministry of Science and Technology. Special funds have also been provided by the Government of NWFP on the recommendation of Members of the Provincial Assembly for installation of plants in their constituencies.

Summary

Community Participation in Micro-Hydropower Development

Ghulam Saeed Khan

The Aga Khan Rural Support Programme (AKRSP), established in 1982, is a private, non-profit organisation established by the Aga Khan Foundation to help improve the quality of life of the villagers in northern Pakistan. In 1986, AKRSP started a village electrification programme on a research basis through the introduction of micro-hydropower plants. The objective of this programme is to develop and test technological and managerial innovations needed for MHP potential realisation in small, remote and inaccessible villages. The electrification programme is not meant to replace the existing large electrification programmes of the government but to complement them wherever needed.

AKRSP extends MHP projects to the selected village organisations (VOs) and adheres to its preconceived methodology of intervening in rural development and holding dialogues with a number of VOs. A VO is a mass coalition of all those residents of a village whose continuing economic interests are best served by organising them as an interest group. Such an organisation can be created around a single activity of overriding importance to most of the villagers.

Once the VO is formed and enters into a partnership with AKRSP, the organisation has to meet as a general body on a regular basis, preferably weekly or fortnightly. Secondly, the VO members must make savings' deposits at their regular meeting in order to accumulate capital to offer collateral to credit and finance self-help projects. The VOs plan, identify, and implement projects supported by AKRSP on a grant basis and provide unskilled labour for execution of the projects. VOs also need to nominate members for training carried out by AKRSP in varied specialities such as agriculture, livestock, poultry, forestry, accounts, and appropriate technology. Once the specialists are trained, VOs need to utilise their services effectively and remunerate them from their own resources. Thus, VO members participate in the planning and identification of productive projects and the AKRSP engineers extend technical assistance to the planning process.

A project cannot be extended unless the VO members agree to take management responsibilities for the project. AKRSP follows the same methodology for the implementation of MHP schemes, holding the first dialogue to explain the concepts, the second dialogue to conduct a survey and prepare estimates, and a third dialogue to finalise terms and conditions between AKRSP and the VOs.

The terms and conditions are that the project should benefit at least 75 per cent of the VO members, who develop a financial system through savings, train one member in MHP technology, and manage the project on their own. The VOs also agree to provide unskilled labour and locally available material free of cost for the project. The plant machinery and some other costs are borne by AKRSP on a grant basis. AKRSP also assists VOs in site selection, survey, and preparation of cost estimates in order to install a MHP plant keeping in mind the minimum power requirement of the VO. The power generated from the MHP plants has promoted the introduction of other small industrial and household machinery such as saw mills, flour mills, welding machines, drilling machines, oil expellers, washing machines, and butter churning machines. Therefore, VO members also need to acquire skills in the operation and maintenance of these machines, training for which is also organised by AKRSP.

The management system varies from one VO to another, depending on the ground conditions. Larger VOs with bigger projects constitute an electricity committee for the management of project affairs, while smaller VOs having smaller plants manage them under the supervision of VO presidents and managers. On the whole, the management system is quite easy and does not demand sophisticated and expensive management techniques.

The committees, once formed, are responsible for all the affairs of the plants, including appointment of operators/guards. They also fix and collect the electricity tariff and approve new connections. The committees make sure that each pole has fuses fixed to avoid illegal use of energy. Those who are found guilty are fined. The records of the project and electricity are usually maintained by the chairmen of committees, or managers.

To meet emergency maintenance costs, the committees pool funds through compulsory contributions from consumer members. This is in addition to the income gained from electricity charges. In the VOs, where no committees have been formed, one member, on rotation, assists the president and the secretary in handling project matters. The committees and the office-bearers render honorary services. However, in some instances, they are exempted from paying electricity bills.

Small industries have been established in some villages where MHP plants generate sufficient energy. The MHP plants have given an entrepreneurial vision to VO members and provided some employment opportunities. On an average, the MHP plants have created employment for four members in VO industries, including the operators/guards.

The MHP projects have a positive impact on community exchange, particularly as the project management and maintenance are the responsibility of the community. MHP projects meet community needs and as such the community has to develop a management system through consensus to attain the benefits of electricity.

Summary

Selection of Turbine for Micro-Hydropower Schemes

Samiullah Khattak

Selection of a suitable turbine for any particular hydro site depends upon site characteristics such as available head and flow. Selection also depends on the desired running speed of the generator or of the device powered by the turbine. Other considerations, such as whether the turbine will be expected to produce power under part-flow conditions, also play an important role in the selection. All turbines have power-speed characteristics and tend to run most efficiently at a particular speed, head, and flow.

Often, the device which is driven by the turbine, usually an electrical generator, needs to be run at a speed higher than the optimum speed of a typical turbine and, then, speed increasing gears or pulleys and belts are used to link the turbine to the generator. It is preferable to minimise the speed-up ratio in order to reduce transmission costs, loss of mechanical power, and other technical problems.

Turbines can be broadly classified into high-head, medium-head, and low-head machines. Turbines are also divided by their principle of operation and may be either impulse or reaction types. Each turbine type is best suited to a certain range of pressure head and flow rate and has a numerical value associated with it called *specific speed* which characterises its performance. The *specific speed* relates the output power of the turbine to its running speed and head across it. It does not depend on the size of turbine. The turbine type can also be assessed by relating *specific speed* and the actual working head.

In general, smaller runners are cheaper because they use less material and can rotate faster, therefore requiring less gearing mechanism. Casing costs also tend to be less for a small diameter runner. In practice, there are limits to the lower size of the runner able to handle the flow passing through it, but a well designed turbine always has the smallest runner permissible within these limits.

Another significant factor in the comparison of different turbine types is their relative efficiencies at part-flow. Typical efficiencies of the turbines indicate that that Pelton, cross-flow, and Kaplan turbines retain high efficiencies even when running below design flow, while the efficiency of Francis turbines falls sharply if run below half of their normal flow.

In order to meet the objectives of the MHP programme of PCAT, complex structures and manufacturing processes are avoided by using cross-flow turbines. Locally available sheets and pipes are used in the fabrication of the runner, nozzle, and the housing, and they can be easily manufactured in simple workshops having facilities for sheet cutting, drilling, and welding. The turbine dimensions are worked out from the values of available head and flow at each site. No effort is made for the standardisation of any of the runner dimensions. The runner speed is designed to be in the range of 300-500 rpm in most of the plants. In some rare cases, especially at very low heads, speeds of about 200 rpm have been obtained. The runner diameter is usually 47 cm (18 inches) and the width ranges from 20 cm to 60 cm with 28-32 blades.

The turbine runner is assembled by a simple process, whereby end plates of specified diameters are cut from six mm thick, mild steel plates, and blades are cut from a suitably sized steel pipe. Blades are then welded to the end plates which, in turn, are welded to the shaft running through its centre. The nozzle is made from three mm thick mild steel sheet. It is fixed at the lower end of the penstock and is independent of the turbine. No automatic governor is included in the design. The flow is controlled manually by a gate valve mounted at the lower end of the penstock. The runner shaft is supported by the ball bearings which are secured in a housing fixed on the concrete pads. Cast iron pulleys of suitable diameters are used to couple the turbine to the generator through V-belts. Both locally made and imported pulleys and belts are available in the market.

PCAT has so far been overseeing fabrication of the turbine runner and housing in a private workshop at Peshawar. Recently, other workshops have also been identified in Rawalpindi and Lahore where cross-flow turbines of better quality and sophistication can be manufactured. Two units were tried at a Rawalpindi Workshop. Also, efforts are being made by PCAT to have access to a more established workshop where the engineering drawings are well understood, in order to manufacture more advanced and high quality turbines.

Summary

Indigenous Development and Manufacturing of Very Low Head Micro-Hydel Power Plants

Aftab Sarwar and Dr. S.M. Bhutta

Pakistan has a total annual surface flow of water of 144 million acre-feet (MAF), out of which the canal system withdraws an average of 106 MAF for irrigation. This irrigation system is the largest integrated network in the world serving 34.5 million acres of contiguous cultivated land. The total length of main canals alone is 58,500 km and water courses comprise another 1,621,000 km. In addition to this, there are several thousands of kilometres of *nallahs* and small tributaries in the hilly areas. The water courses get their supply of water to the outlets from the irrigation channels and distributaries where falls of three feet or so are very common. In spite of this huge network and hydropower potential, very few plants have been installed so far to make use of this running water for generation of electricity, despite the fact that most of the villages still go without the facility of electricity. If a hydroelectric turbine was developed to make use of such small falls ranging between one to two metres, the farmers could have access to electricity from a cheaper and renewable source of energy.

The design calculations of a very low head micro-hydropower unit show that theoretical power of one kW can be obtained from a fall of three feet and flow of five cusecs. This turbine would run at a specific speed of 739 rpm, and its operating speed would be 750 rpm. This speed can be increased to 1500 rpm by using 1:2 gear ratio, and an alternator with five poles would generate one kW electricity through this turbine. The runner diameter for this turbine type is calculated at 10.39 inches.

Since the theoretical estimates have confirmed the possibility of power generation at such a low head, appropriate prototypes need to be developed which would be tested and evaluated in the field, by a suitable R & D agency. Necessary improvements must be incorporated in the machinery through such field trials. In fact, improvement of turbines and other allied equipment through field trials and feedback should be a continous process.

It is imperative that engineering, operational, financial, marketing, and industrial evaluation of the prototype be carried out before proceeding further to the next stage of demonstration of the developed technology. When the technology is proven and practically demonstrated, the manufacturing of the units can be started on a commercial scale by the private sector.

The Water and Power Development Authority of Pakistan (WAPDA) is annually losing PRs five billion because of subsidised tariff rates for the rural areas. The annual loss to the government per village is about PRs 100,000. The cost of extending distribution lines to a village is about PRs 1.6 million, and annual recurring expenditure for its maintenance is PRs 35,000 per village. In addition to this, there are capital and recurring expenditures of the generation plants, transmission lines, and grid stations. The realistic cost from thermal power units in a village would be PRs 3.5 per kWh, whereas the cost of electricity from a micro-hydropower plant would be PRs 1.30 per kWh.

Summary

Management of Micro-Hydropower Plants in Pakistan

Dr. Habib Gul

The micro-hydropower (MHP) programme of PCAT aims at benefitting the economically weak and underprivileged segment of the population in the remote rural areas. Untill now, 181 plants have been installed with an overall generating capacity exceeding two MW. Keeping in mind the resource constraints, coupled with increasing demand and popularity of the MHP plants, it is not possible to entertain all the applicants, and more than 200 such requests are pending with the PCAT. Efforts are being made to accommodate the applicants from different areas, and plants are now being installed on the basis of district-wise demand.

PCAT receives formal applications from the local community committee comprised of a group of four to six prominent persons, for the installation of MHP plants near their village. In most cases, these applications are duly recommended by the local public representatives (e.g., Members of national/provincial assemblies, district/union councils, senators, and so on).

The PCAT staff then undertakes an initial survey of the potential sites, discusses various possibilities with the villagers, and tries to identify those with a genuine interest and necessary capabilities. The approach to establish a local suitable, institutional set-up for the individual plant is, therefore, flexible. Two survey proformae, one for assessment of local capabilities and the other for assessment of the potential for the MHP plant are filled in which the head, flow, population, number of houses to be electrified, and other related information is recorded. Based on these reports, the consultant makes the final decision for installation of the MHP plant on a particular site.

Due to limited funds, the decision regarding the installation of MHP plants is based on district-wise allocation and, to some extent, pressure from the public representatives. Subsequently, a formal agreement is drawn between the PCAT and the recipients, represented by a committee or a designated individual, whereby they are clearly apprised of their responsibilities, e.g., undertaking the civil works, supplying and erecting power distribution lines, running and maintaining the plant, and so on. The recipients are also instructed as to what works have to be completed by them and how much money has to be collected for distribution lines. The recipients also agree to arrange availability of one/two permanent person/s for operation and maintenance on the basis of cash payment or other means; arrange for a distribution network to various houses, including in-house wiring; operate the plant within specified limits of load; and arrange for repairs through a local technician or through PCAT. The agreement also points out that the recipients have to pay the cost of repair in case of a breakdown.

Design of the turbine and other components is then undertaken by the PCAT Field Office, Peshawar. The machinery is fabricated at a local private workshop. The components are assembled for testing and then deattached for transportation to the site.

During and after installation, PCAT provides all technical information and installation expertise related to the plant, through training of one or two villagers for future operation of the plant. The necessary instructions for the operators regarding operation of the plant are provided in the form of a printed manual. At the time of installation, the turbine is tested for its speed and the alternator is checked for its voltage. Two completion reports, one for civil works, and the other for installation of equipment, are filed by the PCAT staff.

After installation, testing, commissioning, and proper training of the personnel, the plant is handed over to the community, and, from then onwards, the community becomes responsible for its operation and maintenance. In case a breakdown occurs, the community arranges for its repair on its own, or they may approach PCAT for replacement of a part.

Usually, nominal charges (PRs 10-20/month/bulb) are collected every month by the plant management for maintenance purposes. At some plants, the managers are now using energy meters and collecting the charges on a kWh basis. The committee is also responsible for all other tasks in connection with the plant. The ultimate institutional set-up may be a formally registered cooperative, or it may be an entirely private enterprise, depending upon the circumstances.

During the first few days, a technician from PCAT stays at the plant site to monitor its working and deals with any other unforeseen problem, as well as providing practical training to the plant operators. More recently, a decision was taken that PCAT staff would visit the plant after three and nine months of installation, to check whether the community was managing the plant reasonably well. In case some problems are observed in the running of the plant (technical or otherwise), a decision will be taken as to whether the plant should be left at the given site. Otherwise, steps may be taken to shift the plant (or the removable parts) from that site for future use in some other installation.

Summary

Problems Associated with Private/Decentralised Mini/Micro Hydropower Plants and Some Possible Redressals

Dr. A. A. Junejo

Identifying the problems associated with private and decentralised MMHP systems installed in the HKH Region and their possible remedies, it was found that funding is one of the major problems associated with private MMHP plants. Overall funding for such plants has been very low, and funds for research and development and testing facilities are almost non-existent. In Nepal, reasonable funds, including soft-term loans and subsidies, have been provided for installation of plants, but consistency in these allocations has been lacking. Non-repayment of loans has also become a serious problem. China and India have also spent considerable sums of money on various renewable energy options, including MMHP/SHP.

Lack of coordination among implementing agencies is another serious problem with regard to policies, planning, and execution of MMHP schemes. Proximity of two or more private MHP plants which affect each other's business has also been identified as a problem. Many MHP plants also fail because the owners/managers are not in a position to manage them properly. Some problems resulting from wrong estimations of the power that can be harnessed, load, or economic returns, during the survey and planning phases, have also been reported. Licensing requirements in many countries are not fully defined. Systems for plant performance evaluation are almost non-existent in most countries. There is no integration of MMHP schemes with national government rural electrification schemes, except in China. Many such problems have led to a considerable decline in MHP installations in Nepal.

The costs of indigenously developed MHP plants have also been increasing, particularly in Nepal. The capital costs of MHP plants are up to 10 times higher than the similar capacity, locally manufactured diesel powered prime movers, although these MMHP plants still cost considerably less than the imported equipment. Some of the cost escalations can be attributed to improvements in technology. Economic returns from the plants have been reported to be inadequate. These returns are mainly used for operation and maintenance costs of the plants, and actual profit for the owners is minimal. Technical failures have been frequently reported in all countries. The quality, reliability, and performance of indigenously manufactured equipment is lower than the equipment imported from industrialised countries.

Lack of management capabilities of recipients/plant owners presents another problem leading to breakdowns and financial difficulties. Repair and maintenance facilities in many cases are also inadequate. The level of expertise of operators has been very low, and many major breakdowns could have been avoided if they had been competent enough to sense the early signs of malfunctioning and to act promptly. The groups of people associated with private/decentralised MHP programmes need to be adequately trained on its various aspects, including planning, awareness-raising, survey, design, construction, supervision, quality control, testing, management, operation, maintenance, and trouble-shooting. The group of people ranges from policy and decision-makers; community leaders; technical personnel of the implementing agencies; including engineers and technicians; and plant owners, managers, and operators.

In the specific context of Pakistan, the problems relating to MHP development include non-recognition of MHP by the government as an important source of energy supply, lack of coordination between various implementing agencies, low level of indigenous technology development, low rate of plant installations, low tariffs, low plant factors, water rights and associated social problems, erratic electricity supply and inadequate training facilities for designers, installers, managers, operators, and repairers of the MHP equipment.

The solutions to the above problems include provision of adequate funding for MHP programmes, dedicated and clear government policies, provision of loans and subsidies, formation of coordination committees from various implementing agencies to avoid overlapping and conflicts, establishment of suitable liaison institutions, and proper capability assessment of the recipients. On the economic side, the costs of the indigenously produced equipment need to be lowered in Nepal, and economic returns from the plants need to be improved by proper management, training of operators and managers, and by adopting novel tariff systems. Research and development activities need to be enhanced to make the technology more reliable. Development of efficient end-use devices and establishment of adequate facilities for repair and maintenance of the plants are also needed. These recommendations, if implemented would result in most of problems being overcome, and progress and achievements would have a far reaching affect, as has been successfully demonstrated in China.

Summary

Socioeconomic Impact of Micro-Hydropower Plants

Ghulam Umar Sarhandi and Rauf Ahmed

Convenience and versatility of use have placed electricity in the forefront of the energy scene. Maintaining a reasonable standard and quality of life would not be possible without an adequate supply of electric power, and economic growth would be hampered without it. The demand for electricity is still growing faster than the demand for energy as a whole, especially in countries like Pakistan where the average specific consumption levels are still very low. Hydropower, on whatever scale, provides one of the options for meeting the growing electricity demand, a limited option because of its strict dependence on the characteristics of particular sites and on the location of such sites in relation to the load centres.

Small-scale hydropower implies local generation for small-scale use and can be a better alternative to a centralised supply in far-flung areas where demands for such a scale still exist. Costs of small hydropower schemes in these areas are inherently high, not only because of the scale effect but also because of the remoteness of the sites and difficulties of access, with the result that their economic merit, assessed on conventional criteria of comparative costs alone, often falls short of acceptable levels.

A hydropower scheme differs from other conventional means of power production mainly in its direct impact, i.e., a better lighting source, employment generation, stimulation of economic activity, and improved communications. The added advantage is minimum damage to the environment.

Broadly, the primary impact is limited to the consumers in the immediate supply area of the scheme, whereas the secondary impact results from the induced effect of the primary impact. The secondary impact can be far-reaching even when the restricted supply area of the small hydropower scheme has no more than a marginal affect on the economy, at large. Electrification also supports the transformation of a local subsistence economy to a monetary economy, at least partially, if other necessary inputs are also provided.

Opinions differ regarding the extent to which electrification reduces the consumption of traditional fuels, such as firewood and agro-waste, and hydrocarbons, principally kerosene. Electrification of outlying areas has not always led to the expected reduction of firewood usage nor has it materially reduced the demand for kerosene. Training and consumer-side investment would be needed to alleviate this situation. Any change will probably be very gradual, even where consumers' response is positive.

Summary

The Tyson Turbine - Another Remote Area Power Supply and Water Pumping System

Fazal Rehman, Rashid A. Sheikh, and D. Singh

The principle of operation of the Tyson turbine has been investigated in the 1980s through a number of studies. Various conceptual turbines have been tested, but, except for the Tyson turbine, none of the designs have reached the commercialisation stage. The concept is based on harnessing energy from moving water in a canal, creek, or river by means of a turbine but without the use of dedicated civil structures such as a dam or restriction to increase water flow or head. The Tyson turbine is similar to a horizontal windmill and is the exact reverse of a ship propulsion system with propeller type blades operating in a set of mutually perpendicular axes to the river flow.

The production model of the turbine is a well designed unit for long service life. It is a mechanically balanced and structurally stable system aimed at handling all mechanical forces and stresses that would be encountered during the course of its service life. By carefully choosing materials for its construction, high corrosion resistance and high strength with low mass weight are achieved. The runner is a 1.5m diameter, polyethylene moulded unit. High strength metallic turbines can not sustain impacts of floating debris such as logs, whereas resilient polyethylene material handles these rough conditions extremely well.

In addition to generation of electricity, the Tyson turbine can be equipped with a suitably designed double acting piston pump that has a life between maintenance in excess of 10 million cycles. The output flow rate can exceed five litres/second at very low head, and water can be pumped up to a 100 metres in height. In order to achieve this, the stroke of the pump is made adjustable and two sizes of barrels (cylinders) have been incorporated into the design.

The electricity generator provided in the system is a high efficiency, permanent magnet alternator producing a variable frequency and a variable voltage output that is later rectified to D.C. and used to charge a 48-volt battery bank. At a water speed of three m/s, the electrical system is able to supply 2.35 kW of power continuously. If this power is stored in a battery bank for over twenty-four hours, the battery will have a 56 kWh storage capacity and will be able to supply a peak load of eight kW for five hours continuously. In addition, by sizing the battery for two days' peak load (i.e., ten hours at peak load) the battery will only be discharged to 50 per cent and have a significantly longer life. Furthermore, in the event of the generator being rendered inoperative, an electrical supply will still be available for two peak demand periods.

Quite a number of Tyson turbine systems has been delivered for pumping and electrical power generation purposes in various countries. An order for 200 electrical power generation units is on the way from India where arrangements for collaboration with a local manufacturer are almost final. Pakistan Council of Appropriate Technology (PCAT) has imported four machines with funds from the Australian International Development Assistance Bureau. These include three water pumping versions and a combination for water pumping and electrical power generation.

Further research on the Tyson turbine in tidal flow applications is also underway in an Australian University. Therefore, given that the world's resources in fossil fuel are limited, a time may come when the current, relatively high cost of this form of renewable energy will become economically competitive.

Summary

Mini-Hydropower Programme of the Northern Areas 'Public Works' Department

Abdul Amir

Northern Areas' Public Works' Department (NA-PWD), a federal agency, is responsible for planning, implementation, operation, and maintenance of development projects in the field of communications, housing, water supply, irrigation, power, and construction of residential/non-residential buildings, such as educational institutions, hospitals, and so on, for other government departments.

Northern areas of the country, covering approximately 73,000 sq.km., are inaccessible from the national electricity grid. Nevertheless, the area is richly endowed with mountains, streams, and rivers which make hydropower development most feasible. So far, 59 small hydropower and 11 thermal stations have been constructed by NA-PWD, generating 26.5 MW of power. Five plants with an installed capacity of 29.64 MW are under construction. In addition, five small hydropower plants with an expected installed capacity of 85.30 MW are in the planning stage. The power generated from these plants is used to provide electricity to about 300 villages, covering about 40 per cent of the population of the Northern Areas.

WAPDA, in collaboration with GTZ, is working on a feasibility study to determine the hydropower potential along various tributaries of the Indus. On completion of this study, it is expected that a number of promising sites will be indicated, and these will then be added to NA-PWD's overall planning.

The NA-PWD has been appointed the executing agency for the rural electrification programme under a grant from the Norwegian Government. NA-PWD has commissioned a workshop for repair and maintenance of hydroelectric equipment and it is used for refurbishing turbines. Staff training is also in progress at this workshop. Apart from this, a 1.2 MW hydroelectric power station has been commissioned in Gilgit and is operational. The second unit of the same capacity is in the final stages of establishment at Hassanabad (Hunza), and a third unit of the same capacity will be commissioned for Tangir (Diamer) by the end of 1995. Within two to three years, after completion of the projects under construction, about 60 per cent of the population will have access to electricity. Planning, implementation, and operation of these hydropower plants are being carried out by NA-PWD engineers.

The turbo-generating sets are either procured from China through barter trade between the two countries or the equipment is purchased through international tendering. The department has installed German, British, Norwegian, Swiss, Austrian, and Chinese units at various plant sites having cross-flow, Francis, and Pelton turbines.

The NA-PWD has also tried to achieve the transfer of technology and indigenous production of turbines through collaboration between the Heavy Mechanical Complex (HMC), Taxila, and Bi-Water of the UK. HMC has successfully manufactured almost all turbine parts except runner. It is hoped that, in the near future, HMC will acquire this technology, and turbines will be designed and manufactured locally. This will boost the country's hydropower activities.

To solve the water rights' problem, NA-PWD normally selects sites either ahead of the headworks of irrigation channels or water from tailraces is again fed to irrigation channels. To tackle the operation and maintenance problems, NA-PWD trains its operators on the job, and they are supported by a Task Force from the workshop. Since technicians and engineers are readily available on the spot, technical problems are, therefore, no longer prolonged.

It is worth mentioning that only one power station was damaged due to boulder slides from above; the rest of the plants throughout all over the valleys, have been functioning satisfactorily for the last 30 years.

Summary

Economic Feasibility of a Small Hydropower Station at Lower Bari Doab Canal, Mian Channu, Khanewal District

Shaukat Khan and Wahaj us Siraj

This paper describes the economic feasibility of a low-head small hydropower plant on a canal fall, namely, Lower Bari Doab canal at VR Bridge, Mian Channu, Khanewal District. The technical data on the site reveal that out of a water flow of 38.9 m^3/sec, about a 3.4 m^3/sec flow has already been diverted through 10 traditional flour grinding mills and about a 35.36 m^3/sec flow is falling over eight weirs, each having 0.644 m in width. A flow of 28 m^3/sec can be taken for practical purposes. The crest level is 149.8 metres, the upstream water level is 152.1 metres, and the downstream water level is 148.7 metres. With a net head of three metres and turbine efficiency of 80 per cent (imported units), eight sub-units (water turbines) can be installed, one on each of the existing weirs, to generate 640 kW of power (80 kW from each unit).

The total investment cost on the plant will be PRs 32.30 million which includes PRs 21.80 million as equipment costs, PRs 2.50 million as civil works and installation costs, PRs 1.80 million for transmission, and distribution costs, and PRs 1.50 as planning and management costs. The annual operation and maintenance costs for the plant will be approximately PRs 1.00 million. Assuming a plant life of 20 years, a discount rate of 20 per cent, an inflation rate of 10 per cent, and yearly electricity production from the units at 3.96 TWh, the cost-benefit ratio varies from 1.19 to 2.99 for four varying energy selling prices, i.e. PRs 1.00 to PRs. 2.50 per kWh and a payback period of 19 to six years respectively.

A comparison of electricity charges actually paid by the consumers to WAPDA indicates that one unit of electricity costs the consumers PRs 0.80, PRs 3.22 and PRs 2.20 for domestic, commercial, and industrial consumers. If an industry consumes less units of electricity, the actual charges per unit could be as high as PRs 32.57. The cost of electricity generated by the SHP plant will, therefore, be more economical, particularly for commercial and industrial consumers.