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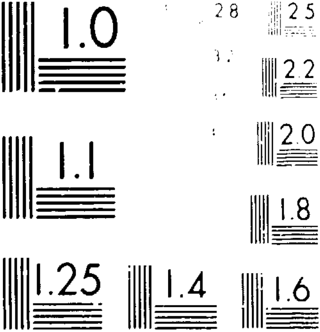
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Distr.
LIMITED

ID/WG.329/37
10 September 1981

ENGLISH

United Nations Industrial Development Organization

Second Seminar-Workshop/Study Tour in the Development and Application of Technology for Mini-Hydro Power Generation (MHG)

Hangzhou, China, 17 October - 2 November 1980

Manila, Philippines, 3 - 8 November 1980

MINI HYDRO POWER DEVELOPMENT IN PAKISTAN*

by

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V. 81-29621

INTRODUCTION

Electrification in Pakistan is carried out mainly by the Water and Power Development Authority, an agency of the Government of Pakistan. The installed capacity is about 3350 MW. Out of a total of 43000 villages, nearly 9000 have so far been electrified. The annual development programme envisages electrification at the rate of 1000 villages each year. At this rate, 34 years will be required to complete the electrification of all the villages.

Since more than two thirds of the total population lives in these villages, it is highly desirable to accelerate the rate of rural electrification, by extending the transmission and distribution lines from central power plants, is quite expensive for rural areas, because of low load density and long distance involved. To improve the financial viability of rural electrification means of reducing the capital and operating cost must be found.

In order to supplement the existing programmes of rural electrification and meeting electricity needs at a reduced cost, the Appropriate Technology Development Organization, Government of Pakistan initiated and developed a programme of rural electrification through micro/mini hydroelectric power plants. By utilizing the locally available resources of technology, men and material it has been possible to install such plants at a very low cost. The paper describes the salient features of these installations.

1. PRESENT STATUS: POTENTIAL, PROSPECTS AND PLANS FOR MHG DEVELOPMENT

The rise in price of fuel and the depletion of its reserves have necessitated the search of renewable energy sources. Small Hydro Electric Power has once again emerged as a promising alternative in many countries of the world. China has more than 60,000 small and medium hydroelectric plants in operation. In the U.S.A., 49,000 small dam sites have been identified as potential hydropower sources.

In Pakistan, Small hydro electric power plants has even a greater role, as fossil fuel reserves are too limited. A large area of the country, mostly in the North has abundant water potential of small capacity. Natural streams of 10-20 cusecs flow perenially and a fall of 20-50 ft could be created easily. In most of these areas, the population is widely scattered, and the demand of electricity is only small. It is therefore too expensive to supply electricity to these regions from the national grid. Annexure 1 presents a comparison of the cost of rural electrification options. It is seen that the ATDO projects have a low capital cost as well as operating cost. The cost reduction has been achieved by simple local design of turbines, use of local material in construction and community participation in the project.

Presently, 20 MHG plants are in operation, their capacities range from 5 to 12 KW; the total installed capacity is 130 KW. Ten plants of capacities in the range of 10 to 50 KW are under construction.

In addition to supplying electricity for lighting purposes, a number of installations supply power to cottage industries and agricultural processes. A typical industrial installation is given in Annexure 2.

The motive power of the turbine drives a main shaft which in turn drives the industrial unit by a pulley-belt combination. The electric generator is also coupled to the main shaft. The industrial units are operated during the day-time and the generator during the night. The industrial centres run directly on the motive power of the turbine include mainly rice husking, flour milling, cotton ginning, saw-mill, wooden lathe and grinding units.

The electrical energy generated at the plant is also used for rural industries at some of the ATDO project. In addition to running the units mentioned above either by individual motor or by a line shaft, electrically driven wheat thresher and corn sheller are operated in the field. The unit is mobile and a long length of flexible wire is connected to the electric motor. The thresher/sheller is moved in the field and electricity is tapped from the nearby distribution line. At one of the project electric welding is also carried out. These industrial facilities are a great help to the local people. Most of these installations are quite far from towns and are difficult to approach. People from adjoining villages bring their agricultural products to the plants and get them processed. It also provides employment to a few people at each plant.

At one location, it is proposed to put up a 10 KW plant which will drive an electrically operated motor-pump set. Water will be pumped from a river to an elevation of about 60 ft where it will be used for irrigating agricultural fields.

The experience gained in the development of MHG plants and their social and economical benefits have encouraged the ATDO to accelerate the rate of extending this technology further. In the current year (ending June 1981) it is proposed to install 30 plants in the range of 10 to 100 KW; thereby boosting rural industrialization. The technology adopted by the ATDO is well accepted by the local people and at some places, well-to-do people have installed the plant entirely at their own cost.

2. ORGANIZATIONAL SET-UP

With a view to accelerating rural electrification and industrialization, the Appropriate Technology Development Organization in the Ministry of Science and Technology, Government of Pakistan initiated a programme of developing micro and mini hydro power plants using local resources.

An outstanding feature of the project is the participation of local community. A chart showing the organizational set-up is given at Annexure 3; a brief account of the responsibilities of each unit is given below:

(a) The Appropriate Technology Development Organization (ATDO) has been established in the Ministry of Science and Technology and it has been assigned the responsibilities of initiating, developing and disseminating technologies suited to local conditions. Development of MHG is one of its several activities. It provides funds for research, development, demonstration and dissemination of the technology of MHG. In addition to meeting the cost of technical staff, at the ATDO in the initial stages borne the full cost of the turbine-generator plant. Presently, the ATDO is sharing the cost of technical services. Selection of site, fabrication of turbine, procurement of accessories and installation of the machinery are the responsibilities of the ATDO. It also provides necessary guidance and technical data on other aspects of the MHG e.g., civil work, electricity distribution, system and rural industrial plants.

(b) The Faculty of Engineering, University of Peshawar, provides technical services to ATDO in the planning, design, fabrication, supervision and testing of the plant.

(c) The Provincial Governments share the cost of the Generators and meet the full cost of turbine and its accessories. It also organizes co-operative societies in the villege for the execution and management of the plant. It provides loans and advances to the societies for meeting part of the cost of the plant and for purchase of industrial units.

(d) The local community, in the form of a co-operative society is responsible for the construction of the civil work of the MHG. They provide labour and building materials. The cost of distribution wires is also shared by the community. Management and operation of the MHG are also the responsibilities of the local community.

3. TECHNICAL AND ECONOMIC DATA

In view of the fact that every site for MHG installation has its own features, e.g. water available, head, location of the plant in relation to the population; no two sites have exactly the same data. In deciding about the location of the plant, a comparison is made regarding the cost of power channel and the cost of distribution lines. In most cases, it is more economical to keep the power house close to the population, which may involve making long length of power channel.

Useful data on few of the ATDO plants are given in the Annexure 4, 5, and 6. Annexure 4 shows a wide range of operating conditions and turbine dimensions. Annexure 5 and 6 give the break-up of the capital cost and running cost of a typical 10 KW plant. For plants of other capacitor, only the cost of generator and the distribution wires vary significantly; other cost show only little variation. An analysis giving the cost of generation is given in Annexure 6.

Details regarding the responsibilities of construction, management and operation have been given earlier in the paper.

4. SALIENT FEATURES OF THE MHG SYSTEM

Procedures and designs have been involved, keeping in mind the objectives of the programme and the education and skill of the local people. In most cases, people use natural streams to run the ancient types of water mills. They are familiar with the technique of diverting water from the main stream and dropping it by 5-10 ft. In the MHG system practiced by the ATDO, simple methods have been evolved, which can be easily understood by local people who are not in a position to study drawing and construction manuals. They are encouraged to use their traditional skills modified whenever necessary. The salient features of the MHG system applied in Pakistan are described below:

5. ASSESSMENT OF POWER POTENTIAL

Output power at any hydro-electric station is directly proportional to the product of 'discharge' and 'fall' or 'head' of water. Obviously the assessment of power at any site involves the determination of 'streamflow' and 'head'. The flow is measured by using a 'float' which has been found as the only appropriate method. Setting up of stream stations will be too expensive considering high cost of transportation; installation and maintenance. The fall is usually determined by finding the difference of elevation between the penstock entrance and wheel inlet. This is accomplished by using an alimeter. Precise levelling procedure, although more accurate, is not considered appropriate in view of high cost of levelling instruments, transportation cost and non-availability of trained personnel to handle such instruments. Ready reference tables has been made giving the power available for different combinations of flow and head which can be used by the local people for making an estimate of the available power.

6. INTAKE STRUCTURE

The intake structure is small obstruction built across the natural stream for diverting flow into the power channel. A loose stone and boulder 'bund' of 1' 3" height is constructed by the villages without much cost. This type of construction can raise water level to create sufficient pondage for affecting the required diversion to run s small hydro-electric generator. There is hardly any expenditure involved in construction of intake structure as the material is available on the site free of cost and labour is contributed by the local people.

7. POWER CHANNEL

The power channel is designed for carrying water from the diversion structure to the penstock. The construction of power channel involves digging 1 ft to 2 ft deep by 4-5 ft wide nearly rectangular channels in natural soil without any lining. The exact size of the channel depends upon the discharge it has to carry with a velocity of 2-3 ft/seconds. The cost of construction of 100 ft length of concrete canal (4 x 4 ft. size) is well over Rs. 15,000 whereas an unlined channel of same size and length made according to self help basis is free of cost.

8. FOREBAY

The power channel terminates into a forebay structure to supply silt-free water to the turbine at a constant head. The main function of the forebay is to act as a stilling basin and a tank to feed the penstock. The forebay is constructed in reinforced concrete with a P.C.C. floor. The over all dimensions of forebay are 5 ft in width by 5 ft in length and depth varying from 4 to 5 ft. A simple rectangular or circular entrance made in the wall of the forebay structure serves as entrance. A hand operated vertical slide gate shuts down the penstock in the event of any trouble below the intake. In some cases a stopped floor construction is adopted which helps in further accumulation of silt. The velocity in the forebay is low enough resulting in deposition of suspended particles.

Another opening is provided in the forebay at a higher elevation than the penstock entrance in order to spill the excess water to the waste during part or complete enclosure of the turbine. A threshrack is erect ahead of the penstock entrance to intercept any floating object. Since the forebay is made from reinforced concrete an expenditure of nearly Rs. 500/= is involved in in.its construction.

9. PENSTOCK

A wooden rectangular penstock or a circular steel pipe is used for conveying water from the forebay to the turbine. In the Northern areas the wooden open channel are already in use for driving water mills. The closed rectangular wooden channels has been tried for the first time for diverting water under pressure to the nozzle at the turbine entrance. The channel cross-section is designed to allow the required flow to pass at a velocity 9-12 ft/sec. The wooden channel are preferred because of extremely low cost of wood in Northern Areas and because the villagers can very easily make and repair such channels. The inner surface is made fairly smooth. Steel penstocks have been used in some places but have been found too expensive. Using a 12" diameter steel pipe for 100 ft. of water the cost would be about Rs. 80/= per foot. Whereas under the present practice a wooden channel of equivalent size does not cost more than Rs. 20/= per ft.

10. POWER HOUSE

The size of the Power House depends upon the turbogenerating unit but generally a size 10' x 12' has been selected which provides enough space to accommodate easily a 10 KW capacity unit. The power house building is constructed of dry ruble masonary, with timber roofing. It has been estimated that such construction will cost only a few hundred Rupees whereas 10' x 12' building with stone masonary and reinforced concrete roofing will cost well over Rs. 15,000/=. The entire civil work including the power house the wooden penstock, the forebay, the power channel and the diversion structure are all constructed by making full use of the technology and material available in the villages. The construction work is completed with amazing speed because of the interest taken by the villagers who see the benefit of electricity at their doorsteps.

11. TURBINES

While selecting the type of turbine to be used at anysite the emphasis is on the low cost of the wheel and on utilization of the technology available in the country. The reaction turbines are too expensive for generating electricity on small scale, such turbines are presently being imported along with their accessories, which involves foreign exchange as well. The cost of a reaction turbine will be too high even if it is made here.

It has been found that the impulse turbines can be manufactured very easily because of the simplicity of their construction. Among the impulse turbines, the pelton wheel too is not recommended because of the low head available in most of the cases and because of the difficulty of fabrication of special types of buckets. Another type of impulse turbine known as "Banki" (turbine which is a free-stream radial wheel) has been found more suited to the local condition. The runner of such a turbine is built up of two parallel/circular disks joined together at the rim with a series of curved blades.

12. FABRICATION OF THE TURBINE

A very simple manufacturing process has been adopted for the fabrication of the turbine rotor. End plates of suitable diameter are cut from a $\frac{1}{4}$" thick mild steel plate. Rotor blades are formed into proper curvature by hammering flat mild steel plates of 1/8" thick and of suitable width. Sector-shaped rotor blades of designed curvature and length are thus made. The end plates are marked to indicate the position of the blades, keeping in mind the required separation between adjacent blades. Both the ends of rotor blades are then welded electrically on the discs. Thus, a squirrel-cage shaped rotor is prepared.

For each site, a turbine of appropriate dimensions is fabricated, depending upon the quantity of water and hand available. The unit designed and fabricated by the ATDO have the following range of the main dimensions.

Rotor dia: 15 inches to 21 inches
Rotor length: 6 inches to 40 inches
No. of blades: 12 to 28

The rotor has a through shaft, supported by three ball-bearings. The driving pulley usually a V-type is also mounted as the shaft. The nozzle of the turbine is made from steel sheets cut into proper size and shape and welded to give the designed size of the jet at the wheel entrance.

The technology of fabrication is simple enough for a village level technician to make such wheels. A practice in electric welding is only needed. The average cost of turbine and its accessories is about Rs. 2,000/=

13. THE ELECTRIC GENERATOR

Standard type electric generators of 1 phase or 3 phase 50 C/S, 220/380 V are used on the project of the ATDO. The power rating depends upon the potential available at each site; generators of 3 KW to 12 KW have so far been installed. The generators used are of Chinese origin and have a static excitation system. A manually operated voltage regulator is provided with the generator. The cost of the generator is about Rs. 1200 - 1500 per KW.

A panel board containing the necessary meters, fuses and switches is mounted on a wall of the power house building.

14. THE DISTRIBUTION SYSTEM

As the power house is located close to the village, no elaborate transmission/distribution network is necessary. A simple distribution line, of suitable size bare copper wire, is laid from the power house to the main parts of the village. Usually 8 and 10 SWG wires have been used, the voltage drop is limited to a reasonable value. The distribution lines are supported by pin-type insulators mounted on wooden poles.

15. OPERATION AND MANAGEMENT OF THE PLANT

In the ATDO projects, the plants are operated and managed by the local people. During all the stages of the project, a few representatives of the community work with the staff of the ATDO and gain training in erection and operation of the plant. Before the plant is handed-over to them, they give the necessary instructions. The plant has no automatic control; the operator is therefore, instructed to control the plant by manual means. The flow of water is controlled either by valve or by gate at the inlet to the penstock. The voltage is adjusted by the regulator. Attempt is also made to run the plant at full load by connecting resistive load and switching them off as the consumers comes on the lines. This appear to be an appropriate method for running the plant at normal conditions.

In return to the services of the local people during the construction of the project, the community representatives decided on a small collection as revenue. In most cases a normal collection at Rs. 1/= or Rs. 2/= per bulb is made monthly. The amount thus collected serves to meet incidental expenses.

16. MANUFACTURE OF EQUIPMENT

In Pakistan the manufacture of MHG plant does not present any serious problems. A number of industries in the public and private sector have the necessary capabilities for fabricating the turbine. There is no shortage of technical manpower either. Recently, a 50 KW turbine has been made by a private company.

In case of electrical generator there are several industries having facilities of making rotating machinery. Most of these are making motors of a wide range of capacity and the same facilities can be used to make generators. However, it will involve import of suitable materials mainly electrical steel, components, e.g., pullies, shaft and bearings are made locally. Electrical components e.g. distribution wire insulators, switches are made locally, indicating meters, e.g., voltmeter and ammeters are not made locally, however, they are easily available in the market items.

Commercial manufacture of turbines and generators may become feasible if the demand of such units increases substantially.

17. CONCLUSION AND RECOMMENDATIONS

Conventional method of rural electrification is too expensive and is not justified, particularly when electricity is used for social uplife and running cottage industries. In areas having widely dispersed population, the extension of grid is not only expensive initially but is expensive to manage and operate. It is therefore a pressing need for more economical options for rural electrification. Decentralized hydroelectric power offers a promising solution to the problem. The machinery for such plants can be made locally. By involving the local community the plants can be installed and managed at a low cost.

In order to promote this technology, the following recommendations are made:

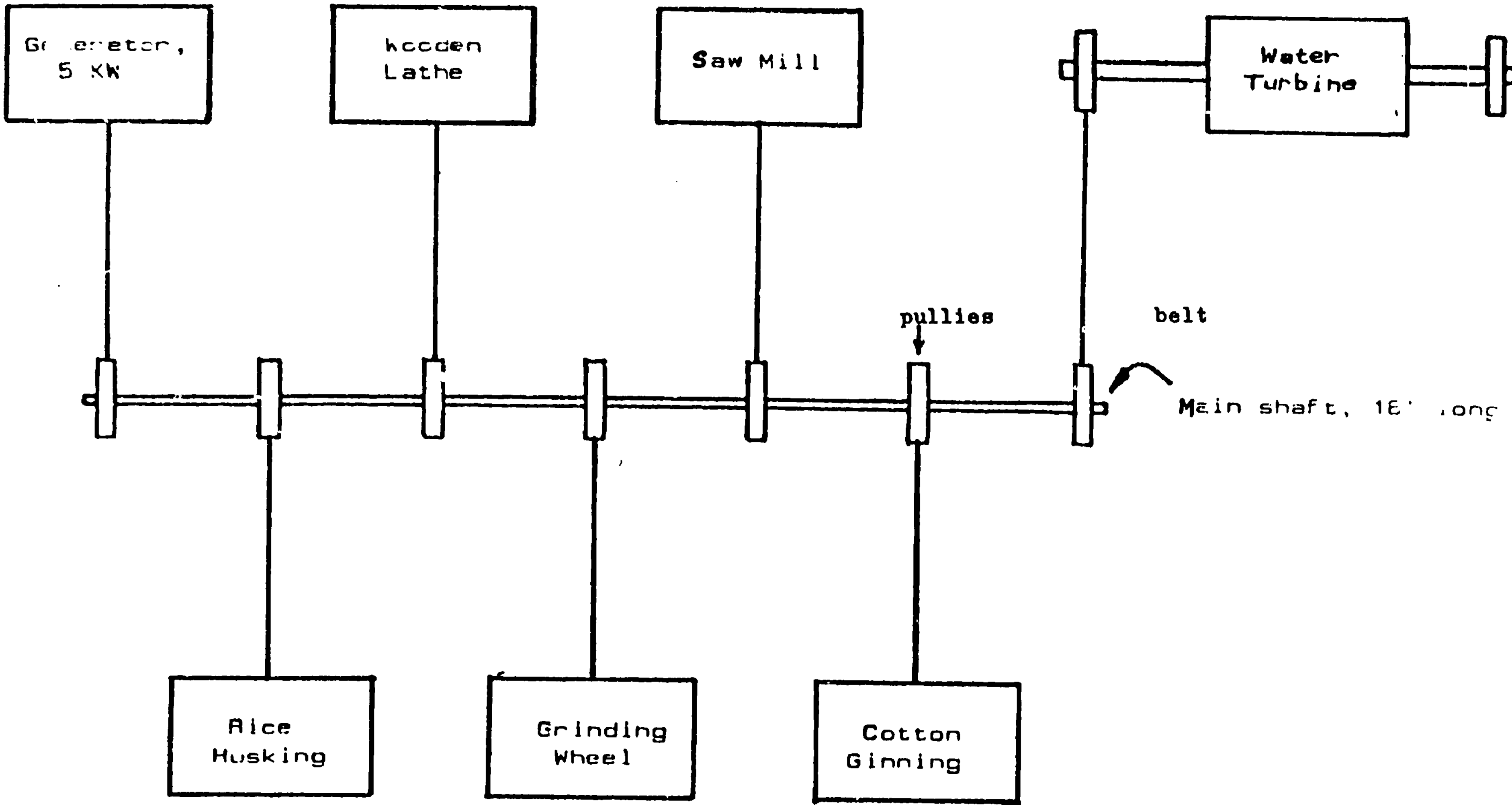
- extensive assessment of potential for MHG be made
- MHG plants be made by local industries
- Policies be evolved for wide-spread application of MHG plants
- rural electric co-operatives be established
- regional workshops facilities be established for repair and maintenance of turbine and generators
- facilities be established for training local technician in maintenance of electric generators, distribution system and domestic wiring
- exchange of ideas, information and experience be promoted through publications and visits
- development of other design of turbines for low head be initiated

Annex 1

COMPERATIVE COST OF THE RURAL ELECTRIFICATION OPTIONS

(AVERAGE VALUES)

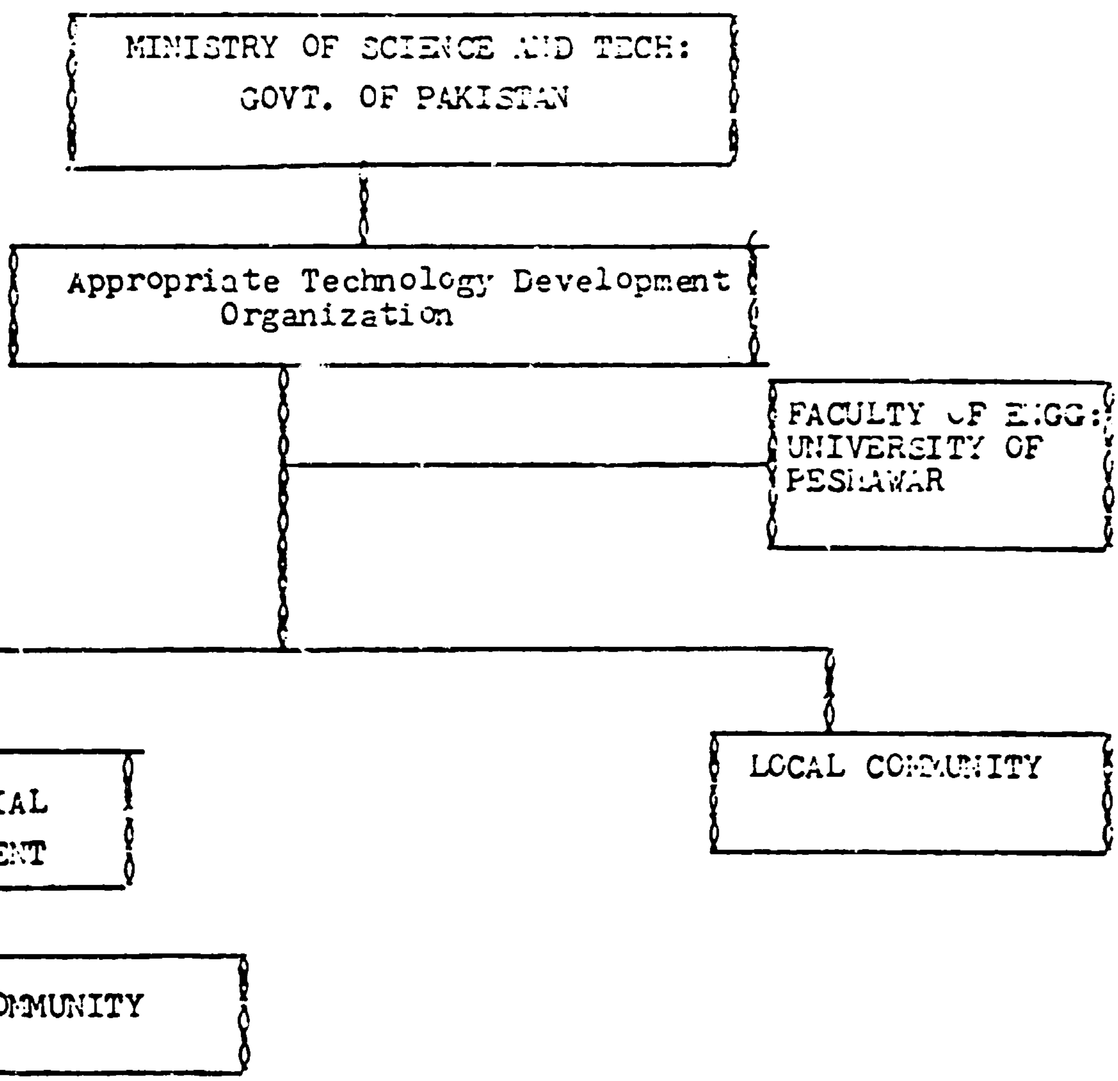
S. No.	Mode	Capital Cost	Running Cost
1 -	Extension of grid	Rs. 500,000 for a village of 100 houses	Rs. 0.35/KWH (Charged from consumers)
2 -	Small Hydro Electric plant - 100 KW plant (conventional design)	Rs. 50,000/= per KW	Rs. 1.0/KWH (Generation cost)
3 -	Mini/Micro Hydro Electric Plant (ATDO DESIGN)	Rs. 3,500/= per KW	Rs. 0.23/KWH (generation cost)



COTTAGE INDUSTRIES IN BISHBAND, SWAT

Annex 3

ORGANIZATIONAL SET-UP



TECHNICAL DATA ON SELECTED PLANTS

Annex 4

S. No.	Location	Water Cusec	Head Ft.	Installed Capacity,	Penstock Size	Turbine Dimension Inches Dia.	Turbine Dimension Inches Length	Application
1 -	Alpuri	15.0	20	12.0	22" dia drum	12.0	38.0	Lighting
2 -	Barkalay	3.0	30	5.0	8" dia pipe	15.0	9.0	Lighting and industrial
3 -	Shang	6.0	40	10.0	10" dia pipe	15.0	16.0	Lighting and industrial
4 -	Shalpin	3.0	30	5.0	8" dia pipe	15.3	9.0	Lighting
5 -	Misghar	10.0	56	12.0	12" dia pipe	17.4	14.7	-do-
6 -	Bishband	3.0	35	5.0	7 x 36" dia pipe wooden channel	15.0	7.0	Lighting and industrial
7 -	Bella	2.5	65	5.0	8" dia RCC pipe	12.3	6.0	Lighting
8 -	Paras	8.0	105	20.0	10" dia pipe	18.4	10.0	Lighting and industrial
9 -	Lamotal	10.0	40	12.0	18" x 12" wooden channel	15.2	23.0	-do-

N.B.: - Plants at 7, 8 and 9 are under construction

Annex 5

COMPONENTS OF CAPITAL EXPENDITURE ON A 10 KW PLANT (RS)

CIVIL WORK	TURBINE AND ACCESSORIES	GENERATORS	TECHNICAL ASSISTANCE	TOTAL	FIXED COST RS/KW INSTALLED	DISTRIBUTION SYSTEM	FIXED COST RS/KW DELIVERED
7000	2000	14250	3520	26770	2,677	8,000	3,477

COST ANALYSIS OF A 10 KW PLANT (RS)

FIXED COST	ANNUAL EQUIVALENT COST i = 13% n = 25 years	RUNNING COST	TOTAL ANNUAL COST	KWH GENERATION AT 30% PLANT FACTOR, KWH	COST OF GENERATION RS/KWH
26,770	3,652	,350	6,002	26,280	0,23