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MICRO HYDRO POWER FOR RURAL DEVELOPMENT

Lessons Drawn from the Experience
of the Intermediate Technology Development Group*

by

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INTRODUCTION

Over the last few years there has been a very great interest in the use of small scale hydro electric power for developing countries having good water power resources. However experience of the mini hydro programmes that have been undertaken in several countries shows that the success of these schemes is very variable. It has been demonstrated in many places that small hydro power can make a very important contribution towards rural development, and that small hydro electric plants can produce power more cheaply than any available alternatives, such as diesel or extension of high voltage grid. However there are also several schemes which have not been as successful as had been hoped and have proved to be expensive and sometimes unreliable. After a few years of looking at many of these projects, both successful and unsuccessful I would like to offer my conclusions about the differences between a successful and an unsuccessful approach and to give some proposals about how very small schemes should be tackled. I should say that although I will be talking about micro (that is up to 100kW) and mini (100kW - 1MW) schemes my experience is more at the micro end of the range. However I believe the lessons can apply to both.

THE APPROACH THAT DOES NOT WORK

Until recently the conventional wisdom amongst aid agencies and multi-lateral funding bodies such as the World Bank was that small scale hydro electric plants cannot be a viable economic investment in developing countries because of high capital costs and low load factors. The reasons for this opinion are various. With a lack of experienced small hydro engineers the aid agencies have been obliged to approach small projects in the same way as
they would large projects, that is to use large international consultancy firms to carry out feasibility studies, design and contract supervision. The consultants themselves have tended to use a scaled down large hydro approach and to offer detailed design of the civil works, often specifying the use of large quantities of concrete, and to design and specify every last detail of the civil, mechanical and electrical equipment. Clearly this approach is inappropriate to very small schemes. Quite often the feasibility study alone for one scheme would cost more than the total implementation should have cost. Further, as is often the case when these projects are carried out on behalf of an electricity supply corporation the load remains very low after completion. (We looked at several mini hydro plants installed in India and found that few people could afford a domestic electrical connection, there was no industrial load and load factors remained very low because lighting was the only use for the power. No attention had been paid to encouraging industrial load growth.)

If the supply of power is to do anything for rural communities it has to increase local productivity, and that needs encouragement. Simply making electricity available is not enough.

Another problem has been that, with consultants specifying the precise details of the machinery there has been little opportunity for manufacturers to make use of their standardised designs and very little opportunity for developing country manufacturers to make any contribution at all. This has kept equipment costs unacceptably high.

I believe that in the next few years these problems will be overcome in many countries, but viable projects will only result from:–

1. Establishing a local management and engineering capability.
2. Keeping capital costs down.

3. Achieving a high load factor.

GUIDELINES FOR SUCCESSFUL MINI/MICRO HYDRO PROJECTS

LOCAL MANAGEMENT CAPABILITY

If these projects are to be widely disseminated in a developing country they must in the long term be locally managed. The management tasks are spread over the planning, implementation and in-service (operation and upkeep phases).

1. Planning

Feasibility studies involve surveys to establish the demand for power in remote rural communities, in areas of good hydro power potential. The surveys have to identify possible industrial needs for power such as for processing of crops (oil seed pressing, corn grinding, saw milling, ice making etc.). All these types of activity will improve the productivity of local labour and thus increase income in a measurable way. This has the effect of providing the means to repay the cost of the plant and to raise the real economic development of the people.

The ownership of the plant has to be considered at this stage. It does not have to be owned by a utility company - in fact this is often a clumsy way of running things. It is often much more desirable for a plant to be owned by an entrepreneur who will use most of the power for small industry. More desirable, but less easy to manage is the sort of project that we often aim for - where the power plant will be owned by the rural community who will use the power plant as one of the
assets of a cooperative to boost local productivity and to provide domestic power as a by product.

Raising the finance for these projects may need political or aid agency intervention in the first instance until the technology is familiar.

Hydrological surveys often need to be done to establish the power generating capacity of potential sites on suitable rivers at the most suitable diversion point. The method of doing hydrological surveys can be considerably simplified providing that good rainfall-run-off relationships are available for a nearby catchment area of similar soil structure. There are very often good flow gauge records from nearby large rivers that have been obtained for irrigation or large hydro use. It is also necessary to have the best possible rainfall estimate for the area. From the catchment area the annual flow duration curve can then be estimated using adjustment to take account of the fact that the very small catchments are more influenced by flash floods after short heavy rainfall. The annual flow duration curve has to be interpreted carefully. Many tropical countries have a highly seasonal rainfall pattern and it can be an expensive error to size a plant to take advantage of high flows over a short period of the year and have to make up the short fall over a long dry season with diesel power. The match of seasonal power availability with seasonal crop processing needs should also be considered, and the plant should be chosen to suit the principal industrial application.

Spot measurements of river flows are necessary to verify the prediction and we have used dilution gauging using 'gulps' of salt solution injected into the stream and then measuring the conductivity profile at a point.
further downstream as the diluted solution passes by. This method has given very good results. Ideally flow variations will be recorded using a measuring weir over at least the dry season, preferably the whole year. However this is seldom convenient or reliable.

2. Implementation

The survey leads to the design of the installation: diversion weir, desilting basin, diversion canal, forebay tank, screening, penstock sizing and routeing, power house layout and choice of turbine and generator, all of which should be done by a local engineering team. Much can be done to produce standardised designs of weirs, intakes, canals etc., which can be sized for each individual site while keeping the design and construction methods standard. Small firms of contractors can then be used and will soon become familiar with the various components. Civil work costs can also be kept down by using masonry in preference to concrete, unlined earth canals where possible and using plastic pipe as opposed to steel (although sometimes there are good reasons for using steel or concrete). In our experience it is very seldom worth incorporating a dam for storage because of the expense. Diversion weirs should be low to minimise damage from boulders during floods.

A small local engineering team has to be established to supervise the construction and installation, and if possible the members of that team should be trained in all (civil, mechanical and electrical) aspects of the technology.
In Service Management

It is possible to design micro hydro plants for unattended operating and to have a minimal need for operator intervention. Obviously one or two operators do need to be trained to carry out daily maintenance tasks such as trash rack cleaning, checking canals for overtopping, flushing silt traps, adjusting water flow and checking voltage and frequency. They should also be able to carry out first level maintenance such as bearing changes, and basic electrical fault repair. However all more complex routine and corrective maintenance will require access to a small regional team of small hydro engineers, whose technical training will be thorough and multi-disciplinary. With small remote sites it is simply not feasible to have separate mechanical, electrical and civil engineers in maintenance or installation teams. Where the plant feeds one principal industry such as a sawmill then the operators should be concerned both with the equipment of that industry and with the hydrc power plant.

CAPITAL COST CONSIDERATIONS

ELECTRO-MECHANICAL EQUIPMENT

We have worked with organisations in developing countries who have organized the manufacture of turbines locally (particularly cross flow turbines and pelton wheels). In other cases we have helped supply complete turbines from the UK but using designs that could later be reproduced locally. I believe that manufacturers from industrialised countries can afford to help set up the production of at least part of their machines in
developing countries. For example Tampella have helped a manufacturer in India set up local assembly of their turbines importing only some parts. We are planning to arrange the same thing in Sri Lanka with pelton wheels from a small British company. It is simply not realistic to suppose that these very small projects will continue to be totally organised by foreigners. The only way mini hydro will increase rapidly is through initiatives taken by the developing countries themselves, helped by industrialised countries which are willing to train them and transfer at least part of the technology. Of course the generators at least will often need to be supplied from outside for many years to come.

In general for turbines smaller than 100kW we recommend choosing from:-

Fixed pitch propeller turbines for low head.

Cross-flow or turgo wheel turbines for medium heads.

Multi-jet pelton wheels for high heads.
(All with either direct or belt drive to the alternator.)

Quite often, if access to the sites is not too difficult it can be worthwhile to consider direct mechanical drive for some operations for sawmilling or corn milling, with an electrical generator driven simultaneously to provide electricity if required. However in most cases all demand for power will be electrical.

For sets up to 150-200kW operating independently we have used electronic load control since it allows the use of simpler turbine design and avoids the use of complex mechanical governors. The load controllers have proved to be very reliable and easy to set up. Of course if there are a number of small
hydro plants feeding into a supply grid then some other method must be used such as induction generators. Overall capital costs for a complete micro hydro plant, including electrical distribution can be typically US $1000 - 2000 per kW, provided that local labour is used for construction.

ECONOMIC VIABILITY - ACHIEVING A HIGH LOAD FACTOR

I have said that the demand for power must be evaluated from the outset, and if necessary encouraged to build up. This cannot be done by people coming from outside, unprepared to learn about the community. Our most successful projects have been done in collaboration with local rural development organisations, who are able to identify the real needs for power - to replace or improve on manual or animal powered or diesel powered processes, and to introduce new processes, which are only made possible by the introduction of power. Examples of village industries we have powered or are planning to power from micro hydro plants include:-

- Saw milling
- Grain milling
- Rice Hulling
- Oil Seed pressing
- Coffee hulling
- Sugar cane crushing
- Wool processing (yarn preparation)
- Crop dyeing (using off peak electricity)

Other potentially attractive uses include ice making and chilling for cold storage.

It will be noted that the majority of these uses are for processing of local crops. The demand for domestic power in remote rural areas of most Asian and African countries is likely to be slow to build up. (Typically less than 20% per year.)
It is our experience that, when asked why they would like electric power most villages will say for lighting and cooking, to displace kerosene and fuel wood. The cooking is a major problem because of the resultant peak power demand, which would very soon exceed the capacity of the plant. We have used a technology used very widely in Norway (and maybe Sweden?) when electrical supplies came from small hydro electric plants - the heat storage cooker.

Heat is stored in a heavily insulated cast iron block over 24 hours, (or overnight) until required for cooking. The effect is to decrease the "after diversity maximum demand" from say 2kW to around 400 watts per domestic consumer. As a result a smaller power plant can be used, operating at a higher load factor.

Of course these very small hydro plants supply only say 1km$^2$ - equivalent to secondary distribution from a grid, at 400 volts three phase. For larger plants of a few hundred kW it would most likely prove necessary to go for higher "primary distribution" voltages of 3.3 - 33kV to feed a larger area. This can also justify the use of sites more remote from the load centre.

CASE STUDIES

CHINA

The one country where micro hydro plants have been very widely disseminated is of course China, where some 85,000 plants of less than 6MW have been installed over the last 20 years. Having realised in the 1960's that for vast areas of the countryside extension of high voltage grids was an impossibly expensive way of providing electricity they have encouraged local initiatives by communes to construct small hydro electric plants with the assistance of an extensive network of water power engineers and some 100 water turbine and generator factories. Of course the political organisation and the enormous efforts that have taken
place in China would be hard to reproduce in other countries, but there are lessons that could be applied on a smaller scale. The manufacture of as wide a range of turbines types and sizes as are used in China could not be justified for a much smaller market, so technical efforts at some standardisation and simplification are essential.

There is very clear evidence however that the small hydro electric plants have resulted in a very remarkable increase in the productivity of rural communities in China.

**SRI LANKA**

In Sri Lanka there is an excellent demonstration of how valuable micro hydro power can be. There are some 1000 tea estates (now nationalised) in the country, the majority of which until recently used micro hydro plants to run their tea processing factories. Some of those plants, installed fifty years ago or more are still being used. Many others are being reactivated because of the high cost of the thermal and large hydro power from the grid, and private tea factories are installing totally new plants. We are helping a local engineering company to establish a small team to do surveys of sites and hydrological calculations, to install new turbine generator sets and to manufacture (or assemble) turbines locally. We are also helping a rural community (organised by Redd Barna of Norway) to install their own pelton wheel plant in a remote part of the island, which they will use for various activities including the accurately controlled drying of cardamom, a high value spice. We hope that this will serve as an effective demonstration for other community plants.
SOUTH AMERICA

In Peru, Ecuador and Colombia, all countries with excellent hydro power potential in the mountainous regions, there are already modest Government-run mini hydro programmes, but they may run into the type of problems that I mentioned at the start, even though they can use some local consultancy companies. However, there is plenty of scope for independent initiatives to be taken by rural development organisations working with rural communities. We have worked with one such group in Colombia, and are starting to work with another in Peru. The local communities own the installation and help to install the equipment, which is provided by local engineering companies, (who make very small pelton wheel plants).

NEPAL

Two companies, set up by Swiss aid and by a group of Protestant missionaries, but run by Nepalis are making and installing crossflow turbines driving milling machines (corn mills, rice hullers and oil seed crushers). The technology has been successful and over 100 sets of this equipment has been installed, mostly owned by private mill-owners.

We are helping to build on this experience and using the turbine-mills installed close to villages to also drive generators and sell domestic electricity to the communities. In other cases the plant will be owned by a cooperative. The establishment of a local engineering capability has meant that the capital cost of the plants is kept very low.

THE WORLD MARKET FOR MINI HYDRO

I do not know how to go about evaluating the future Worldwide
demand for mini hydro plants, but I am certain that it will continue to increase and that provided they can offer a helpful, flexible approach there will be good prospects for manufacturers from the industrialised countries. However, the marketing of the equipment is not easy and there is still scope for technical innovation - developing simple turbines, automatic screening, simple electronic control techniques etc.

Countries like Malaysia, Peru, Philippines, Indonesia have recently launched mini hydro programmes, which if successful will lead to a lot more projects. However all those countries want to maximise their own manufacturing input. African countries with potentially enormous need for this technology will take several years to build up a market. Islands in the Caribbean and Pacific are very interested but until a regional engineering capability is established will be very slow to take advantage of small hydro. However small hydro power does have an important role to play in rural development and the more people know about how to use it the better.