Pico hydro for cost-effective lighting

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Theme

Introduction

In communities with no access to electricity, lighting is provided by kerosene lamps, torches or candles, all of which give poor quality light at relatively high cost. Lighting is usually the primary use of electricity, when it does become available, but the cost will depend on the technology used. Traditional water-power technology has often been used in remote communities for small scale processing of agricultural produce. Pico hydropower adapts this technology to meet modern requirements for electricity and mechanical power. Through recent developments pico hydro has become even more cost-effective for rural electrification. There is already widespread use of this technology in Nepal and significant potential in many other countries.

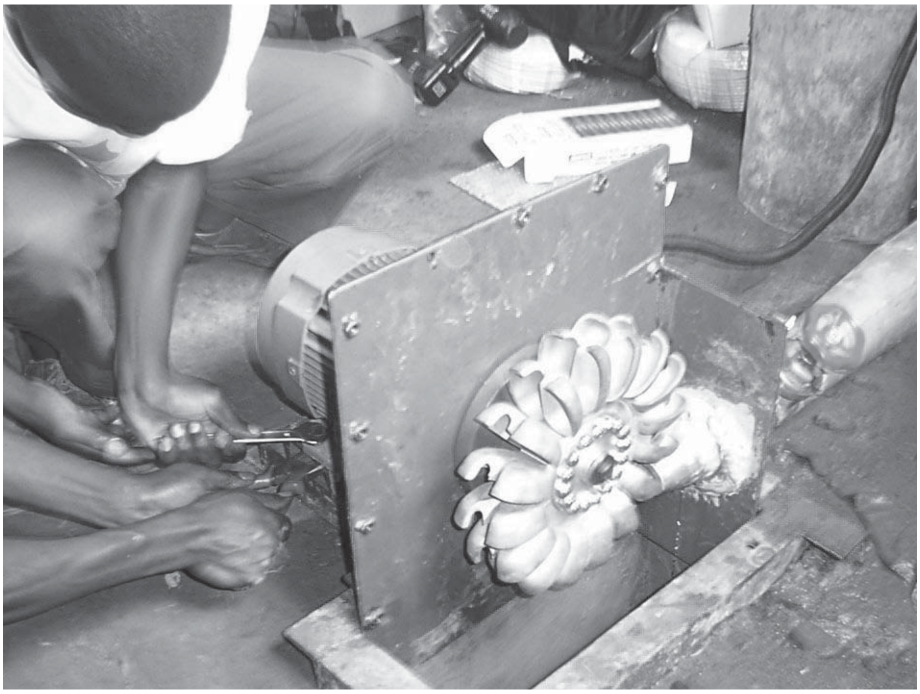

Figure 1 Bolting a Pico Power Pack (*photo: Phil Maher, Pico Energy Ltd.*)

Pico hydro usually refers to schemes of up to 5 kW output. The available power is related to the water flow rate and the available head between intake and power house. Where only low heads are available (less than 10 m) the flow rate must be greater to compensate for the lower water pressure and the cost of pico hydro tends to be slightly greater. There are a number of different approaches to implementing pico hydro, but those that are cost-effective rely on the use of standardised equipment. In some cases schemes supply only one household, while in others a whole community may be served.

Overall scheme design

Designing a pico hydro scheme is time-consuming because each site has different characteristics in terms of head and flow available and the relative position of intake, power-house and consumers. Carrying out thorough site surveys and designing equipment for each site can increase the engineering costs out of proportion to the size of the scheme. One focus of recent research has been the reduction of engineering time through new implementation approaches. Through standardisation and use of new technology, it has been possible to reduce costs while maintaining performance and reliability.

It is difficult to obtain accurate hydrological data from maps or databases, as the catchment areas are too small. Flow measurements, often using low-tech methods, are best made at the driest time of year in order to design the scheme to supply continuously available power. For higher head schemes, height measurements can be made using a hand-held digital altimeter with sufficient accuracy (± 1 m) to carry out the scheme design.

All the site survey data can be collected during one site visit using a standard GPS unit, and this data can later be downloaded to a computer and used to calculate lengths of pipes and cables. Software is becoming available that can optimise the pipe sizes and cable layouts, leading to economic selection of materials while saving many hours of skilled engineering time.

Larger hydro schemes have all of the equipment custom designed for each scheme, but for pico hydro this is not cost-effective. Turbines are often made in a range of standard sizes and adapted to site conditions by changing the operating speed. Local manufacture of turbines can keep costs down, but the designs have to be appropriate for available materials and manufacturing equipment. Pico turbines are often produced in small workshops so the designs have been simplified still further, with no variable guide vanes or spear valve to control flow rates. Often a direct drive to a fixed speed generator is used, in which case the site layout may be designed to fit the closest available turbine option, rather than the other way round. Turbine costs can be further reduced if batch production methods are introduced.

Standard industrial three-phase motors have been adapted for use as induction generators to supply single-phase loads. They have no slip rings or brushes and are therefore more reliable than small alternators. An electronic induction generator controller (IGC) is now being manufactured in several countries in Asia, Africa and Latin America. The controller senses the voltage and uses "ballast" or "dump" loads to maintain the generator speed as required.

Examples of Pico Hydro schemes

In 2001-2 two pico hydro schemes were commissioned in the Kirinyaga district of Kenya (Maher et al. 2003). Since they are demonstration projects, some of the equipment costs were covered through an EU funded project, but the schemes were designed to be cost-effective. Each community contributed time, some materials and finance. A management system was set up to collect monthly charges and oversee maintenance. Households were given the option of one or two compact fluorescent lamps, and they pay according to the number of lamps. Load limiters ensure that each house takes only their allocated share of power.

At Kathamba, a Pico Power Pack (Figure 1) was installed with the turbine runner attached to a shaft extension from the generator. This is a Pelton turbine that can be locally manufactured but still has an efficiency of 70% for only 1.1 kW output. At Thima a centrifugal pump has been used as a turbine (Figure 2). An additional shaft extension has been fitted at the other end of the generator to drive mechanical equipment.

At Magdalena in northern Peru, a low head site uses an axial-flow propeller turbine (Figure 3). Again this is a demonstration scheme, from which valuable information on turbine performance has been gained. It is planned to produce a guide to design (del. of) such turbines as part of a project funded by the Leverhulme Trust (Simpson & Williams 2006).

Figure 2 PAT at Thima (*photo: Phil Maher, Pico Energy Ltd.*)

Figure 3 The low-head turbine at Magdalena drives an induction motor as generator (IMAG) with controller (*photo: Robert Simpson*)

In Nepal and in the northern parts of India, the traditional wooden water-wheel (pani ghatta) has a vertical axis. Improved designs using steel have been successfully implemented. They are cost effective as they require less maintenance and produce more power from the same head and flow so that modern processing machinery, such as rice-hullers, can be driven. Examples of such schemes have recently been installed in Himachel Pradesh, where seven mill owners have been given assistance to install 5 kW generators (Kashyap & Arvind 2006).

Technology Dissemination

For small-scale rural electrification projects there has gradually been a move away from projects funded purely by outside agencies such as regional governments or development charities. Many successful projects are now being implemented through local entrepreneurs and a market is being developed for pico hydro equipment. An example of this is in Kenya, one of the local technicians trained during the installation of the demonstration schemes in Kirinyaga, has set up his own business and has started installing similar schemes in other villages in the district (Figure 4). For successful dissemination of the technology, manufacturers need to be capable of producing a reliable product and consumers need to have access to small-scale finance. Development organisations are taking on the role of enablers within this process.

For pico hydro schemes, the cost per household has been reduced by the use of compact fluorescent lamps (CFLs), which are now widely available. Only 20 watts is then enough power to light a typical rural house, so 2 kW is enough to supply up to 100 households with electricity, with power available during the day-time for charging batteries or driving agro-processing equipment. Similar technology has been installed in remote parts of Thailand under the direction of an organisation called Border Green Energy (BGET 2006). Information on the technology has been disseminated partly through web-based resources.

Cost Comparisons

Detailed costs of pico hydro schemes are often difficult to obtain. Some schemes for which data are available show a range of costs from US $ 1000 to $ 9000 per kW of power output. Some of the higher scheme costs were due to poor scheme design where the actual output was much lower than the intended plant capacity. However, where schemes have been well designed, average costs are around US $3000/kW. A similar figure of Rs 200,000/kW for schemes up to 10 kW has been estimat-

Figure 4 Ngewa (*photo: David Kinyua, Dhetcons Engineering*)

ed for new schemes in India (Kulkarni 2004). For schemes where existing water mills have been upgraded to produce electricity, costs as low as US $700/kW have been reported (Kashyap & Arvind 2004). Taking into account that these schemes can provide power up to 24 hours each day, the costs are significantly lower than kerosene lamps, grid connection or a solar home system.

Small petrol or diesel generators and solar home systems, which would be another environmentally friendly option, typically cost at least five times more per unit of energy than pico hydro (Maher et al. 2003; World Bank 2005). For a household that uses pico hydro to supply 20 W CFLs, the monthly cost would be approximately US $0.80. In comparison, with typical costs of kerosene lamps would be between $1.5 and $3 per month, depending on the price of kerosene. In some countries, kerosene is subsidised, but prices of kerosene are predicted to increase significantly over the next decade, whereas renewable energy costs are likely to be stable. In relation to kerosene lamps, electricity from pico hydro has three other advantages: it reduces fossil fuel use, hence CO2 output, cuts down the number of house fires and provides power for recharging portable equipment such as mobile phones.

Even white light-emitting diode (LED) based lamps are becoming a cost-effective option for rural lighting (Mills 2005). Up to 20 LEDs are incorporated into a single lamp, which can be designed for mains operation. Three 1.5 W LED lamps will give a similar light output as a 10 W CFL. Although the initial purchase price of LED lamps is higher, they will last up to 15 years when used 5 hours each day. The future for pico hydro looks brighter than ever.

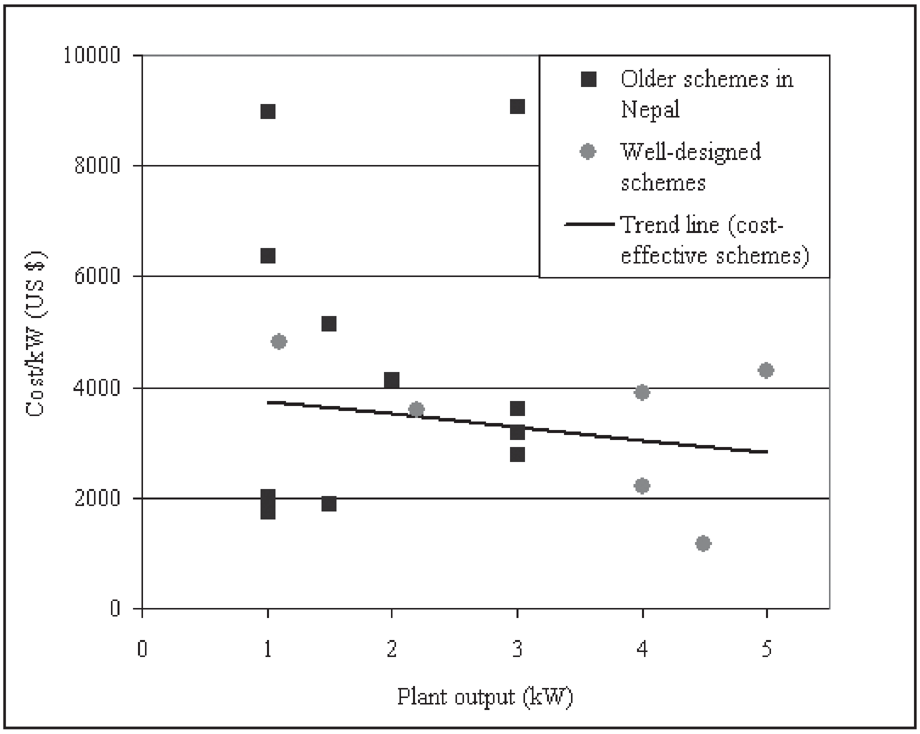

Figure 5 Comparative scheme costs (per kW of output) for various pico-hydro schemes

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Profile of the author

Arthur Williams is senior lecturer in Sustainable Technologies at Nottingham Trent University. He has been involved in micro-hydro research and development since 1987, often working in collaboration with Practical Action.