Nepal Case Study - Part Two

Power distribution, safety and costs

by Nigel Smith and Ghanashyam Ranjitkar

Introduction

This article follows on from the 'Installation and performance of the Pico Power Pack', as described in Issue 6 of the newsletter. It describes the following:

- The design and installation of the electricity distribution system
- The selection and use of load limiters to ensure equal allocation of power between households and to prevent overloading of the generator
- Electrical safety
- Scheme cost

Distribution system

The cable types considered for the distribution system are shown in the table below. Aerial Bundle Conductor (ABC) would have been the preferred choice as it is a strong aluminium cable with a weatherproof insulation which makes it easy to install. However, it was discounted as it would have had to be specially imported for the scheme. Aluminium Conductor Steel Reinforced (ACSR) is the cable normally used for distribution in Nepal. It is strong and relatively cheap, but has a high installation cost because it requires insulators and longer poles, as the conductors must be spaced apart. Also it is not available in small sizes. Insulated stranded copper equipment wire is often used on pico hydro schemes in Nepal as it is easy to install, avoids the expense of insulators and allows cheaper poles to be used. However, it is more expensive than ACSR for an equivalent volt drop and the service life is unknown, as it is not designed for outdoor use on overhead lines.

The distribution system was designed for a maximum voltage drop of 12%, so that by setting the generator voltage at 6% above normal supply voltage the voltage throughout the system will be within +/- 6%. The distribution was optimised using the software described in Issue 5 of the newsletter. Three options were considered: ACSR conductor only, Insulated Copper conductor only, and a combination of ACSR and Insulated Copper. The results are shown below.

It was clear that the combination of ACSR and copper conductors was cheapest, the ACSR being used for the main current carrying section of the distribution and the copper for the rest. To be certain of long term reliability, the ACSR option would have been preferable. However, since the scheme was to be carefully monitored it was felt that this was a good opportunity to investigate the life expectancy of insulated copper conductors, given their financial advantage.

7/20 (7 strands of 20SWG) and 7/22 (7 strands of 22 SWG) copper cable were used as the large number of strands makes the cable more flexible and therefore less likely to break. The only reported breakages on other pico hydros have been with 3/20 cable (3 strands of 20 SWG) which has a smaller overall diameter and less flexibility. The distance between poles was decreased as the cable was tensioned less to avoid stretching of the conductors. The disadvantage of the increased number of poles was reduced as shorter and thinner poles were used because the cable was insulated. Darker colours of insulation were selected as these are considered to be degraded less by sunlight.

Spark gap type lightning arrestors were specified for the distribution, for installation at the powerhouse and close to the main clusters of houses.

Load limiters

Many micro and pico hydro systems suffer from severe overloading because the load connected by the consumers exceeds the output of the generator. Fitting electricity meters in each consumer's house is not the answer as meters do not limit the amount of power that the consumer can draw. The best option is to use current limiting devices, often known as load limiters.

Load limiters limit the amount of current that the consumer can draw. If they draw a current higher than the rating of the load limiter it automatically disconnects the

Cable Type	Availability	Service Life	Cable cost*	Installation cost
ABC	None in Nepal	High	Medium	Low
ACSR	Good except small sizes	High	Low	High
Insulated Copper	Good	Unknown	High	Low

*For same V/km

Cable comparison

Option	Length of ACSR	Length of Copper	Total Price
ACSR only	4,100m	-	$1,924
Copper only	-	4,100m	$2,261
Mixed conductors	650m	3,450m	$1,595

Comparison of distribution options

Transporting a distribution pole

supply. Some load limiters have to be manually reset and others automatically reset, as shown in the table. The consumer pays a fixed monthly fee according to the rating of his load limiter, irrespective of the kilo-watt hour consumption.

By selecting the current ratings of the load limiters so that even with all households drawing maximum current the generator is not overloaded, the supply voltage will not fall and consumers' appliances will work reliably and with good efficiency.

The scheme was designed with a worst case power output from the generator of 4 kW. Using the worst case voltage drop on the distribution of 12% the minimum total power available to the consumers was 3.5 kW. It was agreed with the community that this would be divided equally between the 88 households to be connected and hence a load limiter was required for each house with a 40W limit.

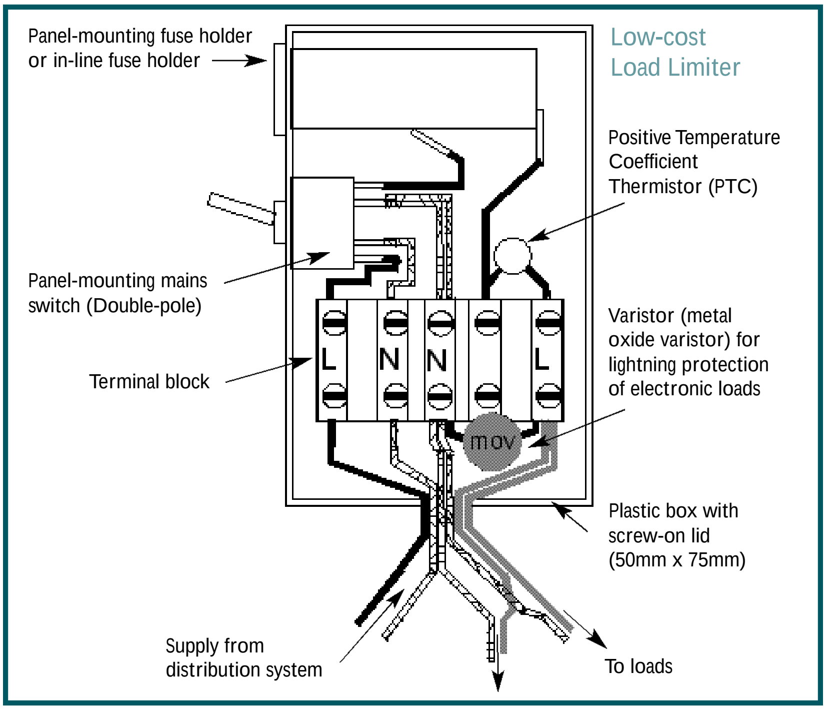
The minimum load limiter current rating was calculated for the 230 volt supply as 175mA. This cannot be achieved with miniature circuit breakers as load limiters as these are not available for current ratings below 500mA. A locally manufactured electronic circuit breaker was available for this current rating; however, the price was quite high at US$15 each. The alternative was a positive temperature coefficient thermistor, which for this current rating costs just US$1 and, as the devices are small, they are cheap to import.

	Thermal Miniature Circuit Breaker	Magnetic Miniature Circuit Breaker	Thermistor (PTC)	Electronic Circuit Breaker
Reset mechanism	Manual	Manual	Auto	Auto
Accuracy	Poor	Medium	Very Poor	Medium-Good
Short-circuit proof	Type dependant	Type dependant	No	Type dependant
Min. Current (A)	0.5 Amps	0.5 Amps	0.01 Amps	0.1 Amps
Max. Current (A)	>50 Amps	>50 Amps	0.7 Amps	5 Amps
Availability	Good for > 6 Amps	Limited	Limited	Limited
Price	Low-Medium	Medium	Low	Medium-High

Comparison of Load Limiter Options

A major disadvantage of the PTC is its poor accuracy due to its poor tolerance and the fact that the tripping current varies significantly with ambient temperature. To reduce this problem a make of PTC with good temperature stability and reasonable tolerance was selected. The tolerance stated by the manufacturer was 170mA to 255mA at 25°C. This was improved upon by purchasing twice the quantity of PTCs required and, by testing, selecting only those with a trip threshold between 190mA and 210mA. The minimum value was selected as 190mA rather than 175mA to take into account the reduction in tripping current at maximum summer temperatures in Kushadevi. In the winter the tripping current will be higher and could result in a small overloading of the generator. The generator has sufficient capacity to allow for this, though there would be a small drop in voltage. The saving in cost was considered to be worth this small disadvantage. A small number of houses were fitted with electronic circuit breakers for comparison purposes. Both of these types of load limiter automatically reset after tripping due to an overcurrent, provided that all the load is switch out.

The diagram shows the connection arrangement. A one amp fast fuse is fitted in series with the thermistor to protect it in the event of a short-circuit. The diagram also shows a varistor which is fitted to protect electrical appliances from the effect of voltage surges due to lightning storms. The decision to fit varistors was taken after a number of lamps were damaged due to lightning (see next issue for details). A seal was used to deter the consumers from bypassing the thermistors.



Electrical Safety

A Residual Current Device (RCD), sometimes known as an Earth Leakage Circuit Breaker (ELCB), was fitted directly after the generator for electrical safety. The neutral was earthed at the generator using a thick copper plate (0.6 x 0.6 metres) buried to a depth of 2 metres. This RCD has a trip sensitivity of 30mA and helps to provide protection against dangerous electric shock. If a person comes into contact with a live wire and is making reasonable contact with the ground the RCD senses that some current is returning to the generator via the earth rather than the neutral conductor and trips, preventing a potentially lethal shock. The RCD is not effective in all situations and therefore shock avoidance through good wiring standards is essential. People can still receive lethal shocks if they are well insulated from the earth and touch both live and neutral conductors.

Fixing the cable

Ideally each house or group of houses should be fitted with an RCD so that a fault only isolates a few consumers rather than the complete supply. However, RCDs are expensive and therefore just a single unit was fitted. The inconvenience of having just a single RCD will be assessed during the monitoring phase.

The scheme installer provided on the job training in house wiring to one of the operators and checked that this was carried out to a high standard. Some households used electricians from the nearest town instead, as the villagers were very keen to have their house wired.

Scheme Cost

The cost per kilowatt output of the generator was US$2,300, which is very similar to other pico hydro schemes in Nepal. There were a number of factors that pushed up the cost: the penstock and distribution lengths were very long due to the site conditions. The price for the Pico Power Pack was high as the manufacturer had to charge more to cover the cost of learning a new design. IGCs, load limiters and compact fluorescent lamps (CFLs) are not always fitted on pico hydro schemes. These factors were offset by the high efficiency of the turbine-generator unit, which helped to hold down the cost per kilowatt.

In many ways the most important cost comparison is the cost per household. At Kushadevi it is currently US$134 per household and this will fall further to US$104 if all 88 households are eventually connected. This should be compared with US$204 per household for a typical pico hydro in Nepal[1]. Furthermore, the quantity of light per household at Kushadevi is generally higher than at existing schemes, in spite of the reduced power per household, as the load limiters prevent the voltage from falling too low and the CFLs are much more efficient than ordinary lamps.

Tensioning the cable

Par t Three

The lessons learnt from the implementation process and first year of operation of the scheme will be described in the next issue of the newsletter. These include mobilisation issues in communities with political and ethnic divisions, installation quality considerations and lightning protection.

Expenditure Heading	Cost (Rs)	Cost (US$)
Civil works (inc penstock)	271,500	4,052
Pico Power Pack	147,000	2,194
Controller (IGC)	44,000	657
Distribution*	132,800	1,982
Load limiters	30,000	448
Lamps (CFL)	28,800	430
TOTAL	654,100	9,763

* Note that this price is slightly different from the design cost due to small price variations and the inclusion of labour costs

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Authors:

Ghanashyam Ranjitkar

Energy Systems

Box 1571

Bansbari

Kathmandu

Nepal

Email: esystems@info.com.np

Nigel Smith

The Nottingham Trent University

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(1) Socio-economic Assessment of Pico Hydro Scheme at Kushadevi carried out by Subarna Kapali