Small Hydropower Plants at Drops on Multi-Use Water Courses

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ABSTRACT

In arid regions of various countries in the world, multi-use water courses take off from storage reservoirs or diversion head works. The canals, running at very mild slopes to maintain maximum command negotiate steeper slopes of the terrain through drops at suitable intervals. The energy of flows at these falls, otherwise dissipated causing thermal pollution of the environment, can be utilized to generate hydropower by mini / micro hydro turbine generator. Canal drops are standardized, thus offering an excellent opportunity to standardize the small hydropower units, resulting in economy. The canals carry regulated and predictable flows free from debris. The flow-duration curves can be easily obtained with precision. The greatest advantage for hydropower generation at the canal drops is operation at maximum efficiency under constant head and discharge for a unit. A battery of hydro units can be installed to be successively started or stopped as the discharge and hence the water level in the upstream reach of the canal rises or falls. Bulb turbines with fixed guide vanes and runner blades in siphons placed directly over suitably modified drop walls present the simplest and most economical solution as all civil works and complicated controls are avoided. Grid connected systems with induction generators will simplify controls. Prompted by the canal water level sensed, the control unit starts vacuum pump to prime a siphon and start a unit or de-prime the siphon by opening to the atmosphere a vent on the siphon hood and thus stop the unit. A number of units on various falls on a canal can remotely be controlled. The bulb units with hermitically sealed generators can be replaced through manholes for maintenance at a central workshop. A small traveling crane over the units and a cabinet for controls are all that are required as auxiliaries. The design case study of such a mini-micro hydropower station on a two meter drop on a canal is presented to exemplify.

INTRODUCTION

Rainfall, confined to monsoon periods, is seasonal in most parts of the world, while requirement of water for various purposes like irrigation, hydropower generation, domestic consumption and industrial use, is perennial or maximum in dry non-monsoon periods. To regulate the excess monsoon flows in streams to supply all the time as per demand, storage reservoirs are created. In arid regions of various countries in the world, agricultural fields are irrigated by canal systems taking off from storage reservoirs or diversion head works on rivers carrying more than required flows all the time. These canals are often multi-use water courses. The canals are given the minimum necessary mild slopes to maintain non-silting velocities so that they run with least head loss to maintain maximum command over areas to be irrigated or to provide maximum head for power generation. The natural slopes of the terrain over which the canals are aligned are generally steeper. Whenever the difference in elevation of the canal bed and the natural ground around necessitates uneconomically high embankments for the canals, the canals negotiate the steeper slopes of the terrain through drops or falls at suitable intervals, depending on the topography of the terrain. Normally, the energy of the falling waters at these irrigation canal drops are killed through special energy dissipating devices. The wastage of energy at these drops drew the attention of hydropower engineers, especially when more attractive hydropower sites started becoming scarce and large storage projects encountered stiff opposition from environmental and socio-economical quarters. Energy of flows at these falls can be gainfully utilized to generate hydropower by small / mini / micro hydro turbine generator units. But the interests of irrigation requirements and power generation through a conventional power house at the drops clashed. Irrigation engineers wanted no interference. Conventional Small Hydropower Plants (SHP) on water course diversions at drops require elaborate construction and not very economical. Bulb turbine–generator units of simple construction with least regulation and minimal controls placed in siphons directly fitted over the drop wall with practically no civil construction can provide economical solution to generation of hydropower at the canal drops. The paper presents a study of such an SHP system on canal drops and exemplifies with a design.

CANAL DROPS / FALLS AND SHP POTENTIAL

Through the outlets / sluices in the storage or diversion head works, required flows are discharged into the main canal heads. Incidentally, these outlets are also sources of SHP, the potential of which can be computed from the reservoir / pond working tables. The main canals thus drawing water from the head works branch out and distribute water for irrigation of fields. The canals run at the least slopes possible to maintain critical (non-silting and non-scouring) velocities so that they can keep to the highest level possible at any point to command the maximum area. Canals are constructed with trapezoidal sections though earthen / alluvial regime canals may tend to take semi-elliptical sections. The bed slopes ***s*** of earthen regime canals vary from 1/6000 to 1/2000 depending upon discharge, nature of soil/silt, and section. They have an average rugosity coefficient, *n* of 0.025. Canals carrying 1 m^3 /s and upwards fall under the jurisdiction of public or corporate authority, field canals of less flow being in the hands of farmers (Ellis 1995). Modern canals are lined with cement concrete with flatter side slopes for convenience in construction. They have rugosity coefficient of about half that of earthen canals. Hence, to convey the same flow with non-silting velocity through similar cross section, bed slopes required will be about a fourth of that for earthen canals as could be seen from the commonly used Manning's equation for velocity, $V=\frac{1}{n}R^{2/3}s^{1/2}$, where *R* is the hydraulic mean radius of the canal section. So, the lined canals can command greater area. The canals running at such very mild slopes negotiate steeper slopes of the natural ground through drops / falls at suitable intervals depending upon the canal water levels required for the command, balancing the cut and fill for canal construction, economy and site conditions. Lined canals running at much milder slopes than earthen canals loose less head and provide much greater falls.

Good designs of falls maintain uniform depths upstream over the normal range of variation of discharge. This is achieved by taking the drop wall to the full supply level and providing in it one or more notches with sloping sides. The theoretically correct shape of the notch to give normal depth at every discharge will be egg-shaped / parabolic, difficult to set out and build. A trapezoidal notch with horizontal sill and side slopes to give normal depth at two discharges (usually, full and half) covering the range of variation gives a practical notch. Multiple notches distributed over the canal width are used to avoid silting of slack pockets of water. The drop walls are built of masonry or cement concrete and are generally provided with concrete aprons upstream and downstream to which SHP units can be readily bolted. Drops are standardized in any system at discrete incremental heights of say, typically 1m, 1.2m, 1.5m, 2m, 3m. Suitable energy dissipaters are built at the foot of the drop to dissipate the energy of the falling water and leave it at normal velocity into the downstream channel. This otherwise wasted energy is what is proposed to be harnessed by SHP plants at the drops.

Flows in the canals at each section and their durations are available from irrigation and water supply requirements. These are predetermined and adjusted occasionally only to take into account the measured precipitation in the command area during any interval of time. The data will be available for each drop site. From this data for any drop site, flow-duration curve can be obtained. Applying to this data the drop / head and efficiency of a turbine-generator set η_{TG} suitable for the fall, the power-duration curve for the site of a fall can be derived as:

$$Power,\ P=\frac{\eta_{TG}\gamma QH}{102}\ kW$$

Where: η_{TG} is the efficiency of the turbine-generator set, the specific weight of water in kg/m^3, *Q* the discharge in m^3/sec, *H* the drop in bed or water level at the fall.

Integration of the curve yields the energy potential of the drop (Fig. 1). Sum of the energy potential at all the drops on a canal gives the SHP potential of a canal at its drops (Kamble 2002).

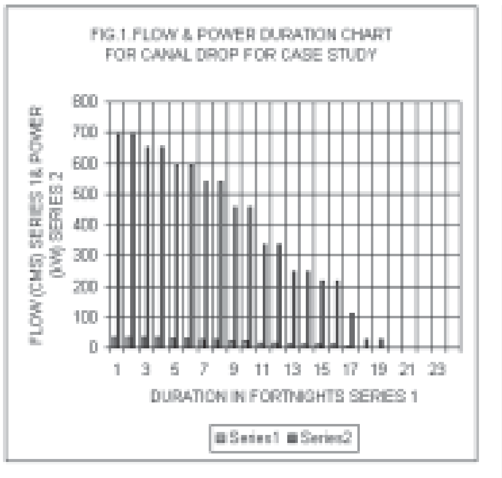
If canal is not designed, the gross fall in the canal bed level can be obtained from the maximum and minimum levels of the command area from its contours. The fall required for the flow through the canal can be estimated as the average slope of the irrigation canals of comparable capacity. The total head that will be available at drops on the canal can then be estimated as the difference between the gross fall and the fall required for the canal flow from the average slope. Then the SHP potential at the drops of the canal can be estimated from the estimated total drop and the average flow Q_{avg} in the canal, assuming an average efficiency for the turbine-generator set, $_{avgTG}$

Estimated average Power,

$$P=\frac{\eta_{avgTG}\gamma QH_{avg}\Sigma H}{102}\ kW,$$

Half the flow at the canal head can be taken as the average flow if it is not precisely known. The estimated average power multiplied by duration of flow gives an estimate to the SHP potential at drops of the canal.

DURATION 1/2 M	FLOW CMS	WATER POWER kW
1	35.27	691.6
2	35.27	691.6
3	33.2	651
4	33.2	651
5	30.38	595.7
6	30.38	595.7
7	27.54	540
8	27.54	540
9	23.91	456.7
10	23.91	456.7
11	17.1	335.3
12	17.1	335.3
13	12.72	249
14	12.72	249
15	11.04	216.3
16	11.04	216.3
17	5.69	111.6
18	1.36	26.67
19	1.36	26.67
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
	390.73	



Energy per year=2,781,615 kWh

ADVANTAGES OF BULB-TURBINE-GENERATORS IN SIPHONS AT CANAL DROPS

The canal flows are controlled and regulated as per irrigation and water supply needs. Therefore, the flows and power are predictable. Flows do not fluctuate and change frequently but remain steady over long periods of time of several days. The flow-duration curves and energy obtainable can be more or less precisely estimated. As coarse silt and debris are excluded / ejected at the canal heads, the canals carry water free from coarse silt or debris. Trash racks can be eliminated / simplified at the SHP stations at drops. Canal drops are standardized, thus offering an excellent opportunity to standardize (Rangnekar 2000) and produce the small hydropower units in mass, resulting in economy and rendering such units competitive. The siphon units pass discharge as and when available under the total head between the upstream and downstream canal water levels at the drop (not under just the head over the sill of the notches as in a normal canal drop) and do not interfere with the other uses including the consumptive use for irrigation and water supply. Siphon units offer several advantages: elimination of inlet gates and dewatering system, convenience of operation, simple controls, improved runaway condition and elimination of ice problems in cold climate (Auroy 1964).

Energy dissipaters, normally provided at canal drops, can be dispensed with thus saving on their cost. SHP plants at canal drops are quite often installed on diversions in more or less conventional powerhouses with avoidable auxiliaries. Such an arrangement renders SHP uneconomical. Bulb turbinegenerator units in siphons placed directly over suitably modified drop walls and bolted down to the floors present the simplest and most economical solution with the bypass and powerhouse eliminated.

The greatest advantage for hydropower generation at the canal drops is constant head at a drop for varying flows. As head is constant and discharge for a unit varies within a narrow range, any one unit will be producing its rated output at the maximum efficiency or going off. Constant head and discharge through a unit makes possible adoption of propeller turbines of simple construction with fixed guide vanes and runner blades. The bulb units with hermitically sealed generators can be replaced through manholes for maintenance at a central workshop thus reducing outages to a minimum. A small traveling crane over the units and a cabinet for controls are all that are required, thus dispensing with a power house structure. Grid connected systems with induction generators will simplify controls. A number of units on various falls on a canal can be remotely controlled. It will be most economical and practicable when a cascade of canal drops is developed by a single agency (Krishnamachar 1997) .

In addition to all the advantages of renewable, clean and economical hydropower, SHP on canal drops as proposed, causes no submergence and has no ecological impact. Over and above, it converts the energy of water at the fall into useful electrical energy and eliminates the thermal pollution otherwise caused by the dissipation of energy of the dropping water. SHP is most widespread.

PROPOSED SETUP FOR SHP ON CANAL DROP (Fig.2.)

Based on the head available at a drop, the specific speed of suitable bulb turbine is chosen. The maximum discharge available in the canal is then divided into a convenient number of parts to get the flow through a turbine. If notched drops are adopted, discharge through a turbine can be taken as the maximum flow through a notch. Number of units should be chosen to cater to the range of variation in discharge and level in the upstream reach of the canal. If all the drops of the same fall on a canal system are considered, and the discharge through each unit is taken as the HCF of the maximum discharges in the canal at each of the drops, it will be ideal for standardization and mass production of units. However, the flow through a turbine may be chosen from the technical requirements of the unit and the total discharge may not be an integral multiple of the flow through a unit. From the head and the flow, the dimensions of the turbine unit are arrived at.

The units are symmetrically located along the length of the drop wall. If necessary, the length of the drop wall may be increased to accommodate the units in a new design. In a notched drop, the notch wall will be up to the upstream full supply level (FSL) in the upstream canal. The notches will have to be plugged and the siphon units bolted down to the concrete floor of the canal at the drop. In case of single rectangular notch without end contractions (rectangular weir type), the sill of the weir will have to be raised to FSL and siphon units placed over the wall bolted down to the drop floors. In any case, the hood of the siphon is above FSL. A footbridge over the abutments, supported by piers over the drop wall where the canal width or length of the drop wall is more, provides access. A monorail traveling crane over the units will facilitate erection and maintenance.

The siphon, housing the bulb unit and proportioned on turbine diameter, rests on the drop wall with its inlet and exit sections submerged under upstream and downstream canal water levels and fixed to the aprons or floors. The siphon is connected at the crest of its hood to a vacuum pump in the control cabinet. The vacuum pump primes a siphon when the upstream canal water level reaches a predetermined level and starts the flow and the turbine. The vacuum pump stops when priming is complete and turbine starts. As the water level falls to a preset value, a little below the starting level, the siphon will be deprimed by a valve on the hood opening into atmosphere, the flow ceases and the turbine stops. The siphon is provided with a manhole just above the bulb unit through which the unit can be installed, accessed, and replaced for maintenance at a central workshop. The traveling crane is located just over the manholes.

BULB TURBINE IN SIPHON

Bulb turbine derives its name from the bulb shaped upstream water tight shell, which, in fact, houses the coupled generator and is considered to be the ultimate in ultra low head turbine developments. The bulb not only accelerates the flow towards the guide wheel and runner but also provides excellent cooling of the generator through its wall over which the cool water passes. The straflow turbines are claimed to offer even less obstruction to flow, but lacks the cooling advantage so important for higher efficiency and smaller size of the generator. As the head and discharge are constant, axial flow turbine with fixed guide vanes and runner blades, with practically no regulation is suggested for canal drop SHP units. Bulb turbines in siphon layout are ideal for microhydel sites at canal drops of 1 to 4 meters. Range of unit quantities for Kaplan turbines are: unit discharge Q_{11} = Q/(D_1^2 H) = 800-3000; unit speed, n_{11} = nD_1/ H = 100-200; where Q is discharge through turbine, n the speed of rotation, H the head and D_1 the runner diameter. Bulb turbines maintain their highest efficiency in the range of specific speed n_s of 650 to 1000, though they continue to have better efficiency than any other type of turbine beyond also (Barlit 2004).

From the developed designs for different ranges of specific speed available with turbine manufacturers, a Kaplan turbine design of suitable specific speed is to be chosen for the head available at a site (drop). While developing a tailor made design for each SHP plant renders it uneconomical, it will be feasible to develop a design for a large number of turbines for similar conditions like head and discharge. From the universal characteristics or hill chart of a proven model of a developed design so chosen, the peak efficiency and unit speed, unit discharge, guide vane angle and runner blade angle are obtained. From the head at a drop and the unit quantities and efficiency η obtained from the universal characteristics, salient dimensions and parameters of the turbine are computed for each chosen value of discharge through a turbine (peak discharge in the canal / No. of turbines) from the equations:

Discharge, $Q = Q_{11} D_{1P}^2 \sqrt{H} \cdot \sqrt{\eta_p / \eta_m}$

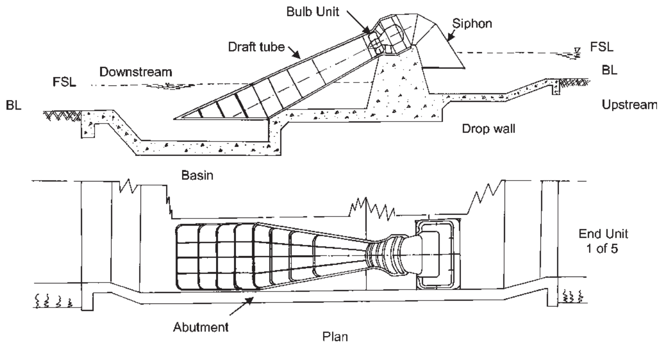
$Q_{11} D_{1P}^2 \sqrt{H}$ as η_p η_m when D_{1p}/D_{1m} is small as in microhydel. Or, the diameter of the turbine runner, $D_{1p} = \sqrt{\frac{Q}{Q_{11}\sqrt{H}}}$, where p refers to turbine being designed and m to the chosen model tested. The speed of rotation of the turbine, $n_p = n_{11} \sqrt{H} / D_{1p}$.

Specific speed, $n_s = n_p \sqrt{P} / H^{5/4}$ to check with $3.65\, n_{11} \sqrt{Q_{11}\eta}$, where *Power*, $P = (\quad Q \quad)/75$, being the specific weight of water. Next higher synchronous speed is chosen and the parameters worked back. Dimensions of Inlet, draft tube outlet, bulb etc., are computed from model applying the proportion D_{1p} / D_{1m} and from statistical data on similar units.

Then the canal and the drop are designed or, if the SHP station is to be designed for an existing drop, the available designs considered. That number of turbines, and corresponding discharge through a turbine, which can be accommodated within the canal width or length of drop wall are chosen. Normally the width of the draft tube (Gubin 1973) exit, being the maximum width of the unit, governs this choice. Submergence at minimum operational upstream canal water level over inlet section is taken equal to runner diameter or half the depth of inlet section. Clearance between the inlet section and the floor should provide an inflow area equal to the area of inlet. These two dimensions are arrived at from pump suction intakes (Stepenoff 1967). If necessary, the floor may be depressed. Vortices, if formed, can be suppressed by wooden floating grills. The exit end of a draft tube normally requires no submergence (Gubin 1973). But the exit end of the siphon needs to be sealed for the siphon to be primed by the vacuum pump. The exit section may be brought to be parallel to the floor of the downstream basin and a clearance equal to the lower of turbine runner diameter or downstream depth of water in the canal provided. The submergence of a third of the runner diameter may be provided over the outlet. The downstream clearance and submergence will be provided by the basin depth required for the drop. The basin may have to be marginally depressed. In an existing drop, the additional basin depth may be provided by constructing an end sill of required height. (Advani 1975).

GENERATOR

The induction generator, mounted on the same shaft as the turbine runner forming a monoblock unit, is housed in the streamlined upstream bulb, filled with dielectric oil under slightly higher pressure than water around. Oil, circulating by impeller action through the generator, dissipates the heat of alternator losses across the walls of the shell over which cool water flows. The oil also assures good lubrication. The diameter of the bulb housing the generator should not be large to ensure proper flow to the turbine. Usually the ratio of shell diameter to runner diameter is kept below 1, though 0.9, 0.8 and even 0.67 has been used. Smaller bulb diameter requires greater length of bulb. The relation that is useful in fixing the dimensions of the generator is: $\frac{n.D^2_{Armature} L_{Armature}}{P_{kW}} = C$. The constant C is useful mainly for choosing the length and diameter of the generator of a unit. It varies with the generator capacity and type of cooling, falling with increasing capacity and improved cooling with compressed air or oil – 0.7 or even 1 for micro bulb units of about 100kW to as low as 0.192 (Rance) or even 0.172 (Baumont –Monteau) for large bulb units with special cooling. Radial arms of rotor should be so shaped that they act as a pump / blower to draw oil / air from both the ends of the generator and pump / blow through vents in the rotor and armature to pick up heat and past the inner surface of the shell to cool. Synchronous speed of the generator, n_{syn} nearest (lower) to the speed of the runner is to be chosen from $n_{syn} = \frac{120f}{N_p}$, where f is the frequency of power supply in the grid and N_p is the number of poles in the generator stator. Having arrived at the power output, synchronous speed, number of poles, dimensions of the bulb and generator, choice will have to be made from the developed designs for different ranges available with manufacturers of bulb sets.



All dimensions are in proportion to the runner diameter (1.677m)
FIG. 2. BULB SET IN SIPHON ON CANAL DROP DESIGNED IN CASE STUDY

CONTROLS

With fixed blade guide wheel and runner of the turbine running under practically constant head and discharge, the governor is eliminated. The main control functions required are starting and stopping each unit at predetermined upstream water levels in the canal and connecting the generator to the grid as soon as the synchronous speed is attained. The siphon constitutes the organ for starting and cutting off the flow. For this purpose it carries on its crown an opening communicating on one hand with an electrically operated valve opening to the atmosphere and on the other hand with a water ring vacuum pump through a valve. The bulb set automatically runs at full load or stops , the starting and stopping being controlled by two sensors fixed at two predetermined levels in the upstream canal, one above the other a few centimeters apart. Relays provoke either the vacuum pump permitting the priming of the siphon and starting of the unit or the electrically operated valve causing depriming.

The sequence of control operation will be as below (Fig.3.):

Discharge and hence the water level in the upstream canal rises and reaches the starting level (L_{start})for a unit. The sensor located at that level sends signal to the controller.

The controller closes the valve (V_{atm})opening the crown of the unit to the atmosphere, starts the vacuum pump and opens the valve (V_{vac})on the vacuum line connected to the crown of the unit.

Water fills the siphon as the vacuum builds up and the flow starts the bulb turbine-generator unit.

Generator attains synchronous speed and the controller monitoring the unit connects the generator to the grid through the transformer.

As the discharge and hence the water level rises to the starting level for the next unit, starting operations follow similar sequence for that unit. The process repeats for all the units at the drop.

When the discharge and water level fall to the stopping level (Lstop) for a unit located a few centimeters Below the starting level, a sensor located at that level sends signal to the controller.

The controller disconnects the generator from the grid, opens the valve connecting the crown of the unit to atmosphere, thus breaking the vacuum and stopping the flow and the unit.

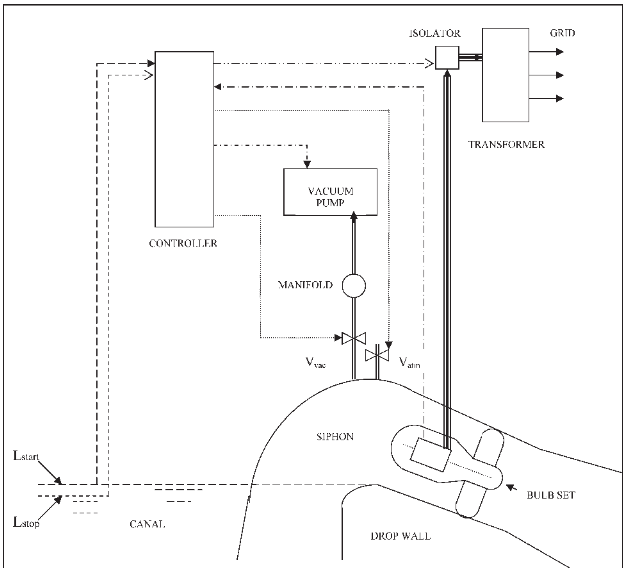


FIG. 3. SCHEMATIC DIAGRAM OF SHP CONTROLS

CASE STUDY

The case of a two meter drop on Shahpur branch canal of Tungabhadra project in Karnataka State of India is taken as an example (Chandrasekhar 1996).

No. of 2m drops=19 in a reach of 27.36 km. Peak discharge in canal = 35.27 to 12.47 m^3/sec.

Study will be made for the canal section and drop with discharge = 35. 27 m^3/sec. The flow – duration and power – duration chart is presented in Fig.1. Hydropower potential at the drop chosen has been computed at 2,781,615 kWh per year. With η_T =89% and η_G=86.5%, energy output of the SHP = 2,141,426 kWh.

Canal designed as alluvial channel:

Discharge = 35.27 m^3/sec, Bed width, b = 23.5m,

Depth of flow, d = 1.8m, Side slopes = 1:1, Bed slope, s=1/6050.

After choosing the number of units, upstream (US) canal water depth at which each number of units to run is computed:

No. of units:	5	4	3	2	1
US depth(m):	1.78	1.68	1.41	1.11	0.73

Drop of trapezoidal notches designed:

No. of notches = 5. Discharge, q / notch = 7 m^3/sec. Depth=1. 8m. Half discharge = 3.5 m^3/sec. Depth, d = 1.2m. q = 2/3 (2g). C $d^{3/2}$ (l + 0.4d n). C = 0.78 for streamlined edges. Sill length l of notch = 0.972m, side slope = 1/2n = 0. 2195. Top width of notch = 1.752m, width for 5 notches = 8.76m.

With min. pier width =1/2d = 0.9 and end piers of 3/4width, Min. length of drop wall required = 13.71m « b of 23.5m. Depth of downstream basin /cushion = 1.4m.

Turbine Design based on universal characteristics of a Kaplan model of a developed design tested at Hydro Research Lab at the National Institute of Technology, Bhopal, India:

Model diameter = 400mm; Head = 2m; η_{peak} = 89%; n_{11}=148.5rpm; Q_{11}= 1760 lps; n_s= 678.4;

No. of runner blades = 4; No. of guide vanes = 16; Guide vane angle = 56^0;

Runner blade angle = 8.6^0. Hence, for H = 2m and Q or Q_p= 7cumecs:

D_{1p} or D = 1.667m; n_p or n = 125.2 rpm; P = 166.11 hp = 122.25kW.

From statistical data on bulb turbines in siphons, pump suction and draft tube exit designs:

Width of inlet section = 4.86 m; Width of draft tube outlet = 4.947m;

Hence, width of channel = length of drop wall required to accommodate 5 turbines = 24.74m. The channel should be marginally widened at the drop by 1.25m.

Submergence of entrance sec. below min. U.S operating water level of 1.2m = 0.27D = 0.45m.

Clearance between U.S floor level and inlet section = D / d /depth of inlet section, 2.5m.

Upstream floor level may be depressed by 1.75m in a new design. As this will encourage silting, the clearance may be limited to d and floor depressed by 1m.

Clearance between downstream floor and D.T exit = D = 1.677m; Submergence = 0.6m /0.5m; Depth of D.S basin = 2.3 /2.2 m. In existing drops, a sill at the end of the basin may be raised by 0.9/0.8m above D.S bed level. These are conservative and could even be reduced further to a nominal 0.15m.

Generator

Speed of rotation, n = 125rpm, matches with the synchronous speed for 50 c/s with 48 poles.

Power input from turbine = 122.25kW. η_G =86.5%. Generator output = 105.75kW. Bulb diameter at generator section generator diameter = 0.82 D / 0.66D = 1.375 / 1.118m; Length of cylindrical part of bulb = 0.55D / 0.53D = 0.922/0.89m; (Auroy 1964/Advani 1975).

Length of armature = 0.333D / 0.311D = 0.558 / 0.52 m. C = 1.08 / 0.709.

Total length of bulb = 1.05D = 1.76m.

CONCLUSIONS

Canal drops offer the unique ideal conditions of constant head and discharge through a turbine that can operate at its best efficiency point all the time, in addition to all the advantages of renewable, clean and economical hydropower. These conditions allow efficient application of simple designs of axial flow turbines with fixed guide vanes and runner blades. Bulb turbines in siphons at canal drops provide the most efficient and convenient solution of simplest design, with minimal controls and civil works. Such SHPs offer practically no interference with other uses. SHPs at canal drops convert the energy at drops, otherwise wasted, doubly saving the mankind from the pollution added to the environment by the energy dissipated as heat at such drops as well as alternate polluting generation of equivalent energy from other sources. Bulb turbines in siphon layout at canal drops can be efficiently applied to the lowest heads of 1 to 4 meters, with highest unit discharge of 800 to 3000 lps, unit speed of 100 to 200 rpm and specific speed n_s of 650 to 1000 with unique technical and economic advantages. While developing a tailor made design for each SHP plant renders it uneconomical, it will be feasible to develop a design for a large number of turbines for similar conditions like head and discharge per unit at cascades of canal drops as exemplified by about 70 turbines under the same head and discharge at 20 drops on a single canal in a reach of 27 km in the case study. Canal and drop can accommodate the bulb turbines in siphon with little modifications and interference with other uses. Induction generators in oil-filled casing with induced flow of oil are more efficient and need 1/3rd smaller generators. With no governors needed, the controls are simplified.

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Hydel Power Development Issues, Counter Measures and Policies in Pakistan

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337-B, Prime Minister's Secretariat, Islamabad, Pakistan.

1.1 Institutional Barriers

In Pakistan, research, development and implementation of small & micro hydel power on commercial scale has been hampered by a lack of co-ordination, institutional support, poor definition of mandates and responsibilities of the organizations. Until May, 2003, there was not a single central agency with the overall responsibility for policy, planning, targets, co-ordination and strategic management of this sector, although there were a number of disparate bodies set up with limited objectives and little coordination amongst different stakeholders. As a result, little or no initiatives taken, so micro hydel application has not been able to progress beyond the pilot or technology demonstration phase, except micro cross flow turbines. Because of the absence of some central agency for overarching, systematic approach to the vast renewable resource deployment, local community-level and distributed energy demand and supply options had not been properly assessed. Areas and aspects where this renewable energy options could offer attractive applications, and the commercial exploitation of renewable power had not been properly evaluated, which could coordinate with agencies and utilities involved in these activities. The impact of the weak institutional arrangements had not been able to promote and finding ways of incorporating these into the mainstream energy planning and supply mechanisms.

1.2 Regulatory Barriers

Regulatory barriers to commercial private power generation are being gradually addressed in Pakistan through new institutional arrangements, although these would require time and effort to become fully effective. However, incorporating improved regulations pertaining to commercial renewable hydel energy projects would be necessary for protecting the interests of this industry and to level the field vis-¨¤-vis more entrenched competitive conventional generation technologies.

NEPRA Act does not explicitly impose any obligation on the regular for towards the promotion of renewable energy. It is known to the investor as to what kind of support mechanism would be provided for the promotion of renewable energy. Whatever, the regulatory tool or mechanism used by the regulator, it is imperative for the commercial viability of small hydel project that the investor is able to recover prudently incurred costs and also earn an adequate rate of return on investment.

1.3 Financial Barriers

Financial and fiscal incentives can play an instrumental role in attracting or discouraging private investment in renewable technologies. The Government of Pakistan has plans to devise a fiscal regime specifically for commercial renewable hydel resource-based power generation similar to the one it successfully implemented for thermal power projects.

Front-end cost of hydel plant is typically higher in comparison to conventional energy technology. In addition, there may be cost of initial development that need to be recovered. Therefore, financing requirements can pose an obstacle. The financing of small projects may be difficult, if as the experience with IPPs suggests lenders have preference for big projects. The financial institutions are generally not geared to finance renewable energy projects, as there are no records of experience of renewable energy to rely upon, unlike conventional IPP projects, where a large crop of professionals are familiar with loan syndication and other financial instruments.

1.4 Technology and Information Barriers

Lack of general awareness, technological knowledge, R, D & D and detailed information on the available renewable hydel potential and energy markets in the country seriously impedes consideration of alternative energy options in the decision-making process, at both the national policy-making and investor planning levels. Such mature technologies as small, micro & mini hydel for suitable areas of applications, especially in remote locations, have not been properly assessed for implementation in Pakistan because of ignorance of relevant technical and cost considerations or the absence of sound data on which to devise renewable energy solutions.

1.5 Policy Barriers

The policy for Power Generation of 2002 has included the development renewable sources of energy but without any thrust on their development. No special effort was indicated to focus on mobilizing technical advancement in these technologies. This has created a vacuum in dissemination of information to create awareness in terms of knowledge and technological characteristics of renewable energy production and use. The policy makers do not feel comfortable. This barrier leads to prolonged delays and lost opportunities. The constitution of the Alternative Energy Development Board (AEDB) is a step in the right direction.

To design, develop and demonstrate various types of small, mini & micro hydel turbines to be manufactured locally.

To improve the quality of local turbines.

To design & develop controllers & governors

To establish linkages among industries, universities and R&D institutions.

To win the confidence of the people about the advantage of small, micro & mini hydel turbine.

People should be able to get plant, equipment easily from the market to install without much civil structure.

These objectives can be met with the R, D & D Laboratories to focus on the design, local development, manufacture & site testing of the hydel turbines and associated equipment. This would help to confirm local proven design of small, micro hydel electrical & mechanical (E & M) equipment to provide with guarantees from the local manufactures. This would facilitate local availability of cheap hydel turbines from the open/local market and simple installation of hydel power plants.

After economical local manufacturing, private parties can install with little civil work & capital cost. It will be easy to maintain by providing training to local people and electricity can be cheaply generated without becoming burden on national grid. These would be competitive with the rural electrification by WAPDA by extending grid.

There is no research & design lab for hydel turbines & equipment in Pakistan, therefore it is proposed to establish Research, Development and Demonstration (R, D & D) Laboratory to meet the objectives as prescribed.

2.1 R, D & D Laboratory

Starting from the basic information existing in Pakistan and to catch with the up-to date research and development of advanced turbine models, this R D& D Lab would focus its activities on micro and small hydropower units in the range of a few kW to 5 MW, with tailored design to fulfill the sites & customer requirements. High turbine performance, a standardized approach to the turbine concept, turbine components and the control system, use of other well-known equipment producers, workshop erection and standardized commissioning will result in the price competitive performance solutions for the most demanding clients. Standardized & proven equipment reduces the client's dependence on the producer during the equipment lifetime and reduces maintenance costs to the absolute minimum. Refurbishment of small hydropower plant equipment is also planned based on the international accumulated knowledge of many refurbished turbines and governors.

2.2 Turbine R & D

The turbine R & D Department would focus on analysis to meet local conditions of all types of Cross Flow, Pelton, Francis, Kaplan, Zero head Tipu and bulb turbine models, site testing and all activities related to turbine and refurbishment. Internationally & locally various turbine type experiences, models developed, and model tests would lead to accumulation of experience and knowledge which would help to guarantee internationally competitive performances and very reliable testing facilities, measuring procedures and accuracy of results.

Turbine models will be designed, produced and tested according to the latest international engineering standards and to meet all requirements for modern turbine model testing.

2.3 Basic Research

Main research areas planned are:

- Research and development of hydraulic shapes & profiles for all parts of turbines, pumps.
- Research and development in the field of numerical flow analysis:
  - Numerical flow analysis of turbines & pumps.
  - Numerical prediction of the efficiency diagram.
  - Development of optimization methods.
  - Reduction of model testing by previous experience.
  - Verification of numerical results by experimental work.
  - Cavitation research by means of experimental and numerical methods.
  - Cooperation with national and international universities, institutes, industries and companies.

2.4 Development & model testing

- Hydraulic design of various turbines based on experiences, gained by systematic research and fluid flow analysis.
- Optimization of old turbine geometry concerning efficiency, cavitation performance, capacity and vibration in accordance with special customer requests.
- Model acceptance tests in accordance with the IEC standard.
- Fluid flow analysis (2D and 3D flow) in a hydraulic machine's stationary and rotating parts, with prediction of its energetic and cavitation characteristics.
- Experimental measurements of velocity distribution in various stationary parts using a Laser Doppler anemometer, 3 and 5-hole probes and hot-wire anemometry.
- Fundamental cavitation research by means of experimental and numerical methods.
- Research and study of dynamic turbine behavior in various operating regimes on model and prototype, and transfer of the results from model to prototype.
- Design and development of test rigs for model testing with inhouse data acquisition software.
- Technical, engineering and technological consulting for evaluation and appraisal of hydro turbine performance.

2.5 Turbine refurbishment

- Pre-feasibility studies of existing hydropower generating units. Analysis of turbine parameters, formulation of methods, prediction & diagnose of fault and deterioration repair, recommending of possible improvements.
- Turbine redesign and model development for refurbished turbines.
- Model testing of existing and redesigned turbines.
- Specific refurbishment projects for all turbine types and sizes.

Electricity being backbone of economy, the large untapped identified more than 42,000 MW hydel potentials provide an opportunity for development in a sustainable manner. The large planned projects would be multipurpose for irrigation, water storage, flood control. Development of hydel power would be byproducts money earning source and instrumental to control the abnormal increase in electricity tariff. The base load requirements can be met through the development of hydel storage dams while peaking demands can be met through high head peaking daily storage projects. This way this provides golden opportunities for meeting the power demand at competitive prices, electrification of villages and development of economy and social services to the people. These projects represent a secure long-term income with manageable low risks, which represents an opportunity.

Nature has provided thousands high head hydropower sites of a large variety mostly in mountains of Himalayas and side hills. In such cases dams are replaced and substituted by weirs for diversion of water from the creeks and provide storage, although small in capacity but large in energy contents due to high heads. So far only 81 sites with 8,880 MW have been studied for details. There are also thousand of low head mini, micro & small hydropower sites located near to the load center at barrages and artificial irrigation canals. At present only 8 sites on barrage with expected capacity of 670 MW, and on canals 539 sites with 510 MW capacity have been taken in the inventory. There are no hydrology or geology problems on these proven sites. All these hydropower projects are environment friendly, as will have no or very little negative impact on environment, which can be mitigated easily. The most significant feature of these projects in that these will not emit any gas and would help to curb global warming, since they replace thermal power plants. Development of these rich potential provides economic benefits, jobs, save foreign exchanges, forests, environments etc. These provide secure long-term income stream with limited risks. Manageable low risk represents an opportunity. Investors can undertake development of huge wealth of hydel projects with confidence based upon the quantification of analysis and proposed mitigation mechanism.

The natural gift of Mighty Indus, main river of Pakistan, is one of the largest rivers of the world, having a length of 2900km. It has a total drainage area of 1,165,500 km^2 of which 453,00 km^2 lies in Himalayan mountains and foothills and rest in the semi erid plains. Its long-term average flow is almost 137 million acre feet (MAF) twice that of Nile. All small and large streams/rivers of the basin drain into Indus river. The opportunities of hydel potential can be imagined from the 37 MAF of water after inland use leftover, being annually delivered to sea, coming from elevation of above, 5,000 meters.

One of the studies carried out in early 80's for putting Pakistan's water resources into its optimum use, with the assistance of Canadian Govt. through consultant Montreal Engineering prepared an inventory and ranking list of various sites. As a result of this study Basha Dam (now called Diamer) site (with or without Kalabagh) was found attractive and based on this other major hydroelectric schemes and ranking are available. During 1990, GTZ of Germany and HEPO of WAPDA prepared a comprehensive inventory of the high heads in mountains and available low head hydropower potential at existing irrigation canal falls & barrages on the river.

3.1 Challenges

The biggest challenge is in the implementation of development hydro power plans prepared on short, medium and long term basis.

Short term plan:08 projects = 792 MW

Medium term plan:16 projects = 6,130 MW

Long term plans:16 projects = 15,633 MW

Their execution require about US$ 0.8 billion for short term; US$ 8 billion for medium term and US$ 29 billion for long term projects.

The investment required for the development of hydropower potential is large so for an optimum utilization a systematic approach is imperative. Therefore following steps are required/being followed to meet the challenges:

Inventories of potential sites, including their hydro-meteorological modeling, hydrological gauging, topographical and geological mapping, geographical information system (GIS), and data bank etc.

Alternative development scenarios with in a hybrid supply system.

Prioritization to be considered by following certain defined criteria.

Detail investigations of sites and bankable feasibility studies.

Professional institutions re-vamping for self-sustaining development

Education, training and public awareness enhancement.

Refinement and updating of data base about hydrology by installing more gauging stations. The data bank although have been expanded by GTZ (Pakistan-German Technical Co-operation) to include assessments of high head hydro potentials on important tributaries by installing 60 new river gauging stations, but even then there is a need to further extend the hydro meteorological network. This data Bank is necessary to provide all kinds of basic information to investors and developers about geological, geographic, discharge data, and sedimentation for all seasons and for extensive number of years. This will provide reliable design inputs.

Integrated development of the transmission system in order to achieve optimum economic dispatch of power for base and peaking requirements.

To clearly define the water rights and royalties or net hydel profits.

Removal of the social or tribal tensions of the effected area.

Improvements and augmentation of infrastructure and communication system.

Mode of implementation of each project (i.e) public, private or partnership.

Management for timely implementation of projects.

Feasibility studies to be prepared by following definite guidelines so that process is standardized for objectively comparison of results of various projects. The proceedings to be transparent and monitored at required milestones. This would help in preparing the feasibility studies to be trustworthy and acceptable to all the concerned parties (i.e.) project sponsors, investors, funding agencies, developers, banks Government institutions etc.

Monitor the implementation of

Quality Assurance Programme.

Modus operandi to monitor progress of implementation of projects.

3.2 Recommendations to Mitigate Barriers

1) Creates conducive & attractive investment environments

2) Provide freely information and guidelines for investors as a handy project portfolio.

3) Overcome bureaucratic attitude by effective one window operation.

4) Political and policy changes to build census among all the provinces and areas.

5) Confidence of environmentalist, investors & local people to be won.

6) Start education & training in the Universities to prepare team of engineers, technicians, and human resources.

7) Design assumption should optimize and take care of natural risks.

8) Expedite preparation of maximum number of bankable feasibility studies. These are time consuming but are the basis for intelligent decisions by investors.

9) Build up & strengthen institutional arrangements especially addressing hydel power development.

10) Arrangements of professionals on contracts for design, manufacturing, construction, operation & maintenance etc.

11) Model agreements to be made available for:

Power purchase

Water use license

Implementation arrangements

Risk compensation

Two part tariff

Insurance of performance etc.

12) Provide analysis of risk events, potential consequences, mitigation options, responsibilities, risk carriers and cost to the project.

13) Accountability required against corruption, red-tapisim to establish transparency and motivation.

14) Development of local manufacturing capabilities for equipment of power technology according to local requirements.

15) Planning and technical capabilities to be promoted.

16) Regulatory Authority NEPRA to be autonomous to play independent & effective role for tariff approval and economic dispatch to win the confidence of investors.

17) Competitive tariff should comprise of any energy purchase price and capacity purchase price with adequate provisions for escalations. The capacity price should be about 60-70% of total tariff. The energy purchase price should be re-structured so that investor and operator has an incentive to regulate daily variations in water flows to ensure "peaking functions" of the high head hydels.

18) Government should guarantee that the terms of executed agreements, including payments terms, are maintained faithfully.

2005 SHP training for African Participants Closed

The 2005 International Training Workshop on Small Hydropower for African countries, sponsored by Chinese Ministry of Commerce, has been held from 2nd Sep. to 26th Sep. at Hangzhou Regional Center For Small Hydro Powder (HRC). Totally 24 participants from 13 countries (such as Morocco, Burundi, Mali, Mauritius, etc.) attended this training.

It is a challenge to adopt French in conducting this SHP training workshop for French-speaking countries, the first kind since the establishment of HRC in 1981. Staff of HRC Secretariat actively learn French and try every way to organize it well. The satisfactory interpretation by the specially invited foreign interpreter who is proficient in French, English and Chinese promoted the quality of the whole training workshop. Meanwhile, we have been striving to seek the teachers who can directly present in French.

African countries face severe shortage of electricity. Mali participant introduced that the electricity coverage in the country is only 12% and in the rural area less than 1%. The situation in other countries is similar. After visits to SHP stations and manufacturers in China, participants felt that SHP technology in China is proven, equipment reliable and price reasonable. Class monitor and the participant from Mali commented in his speech at the closing ceremony, “The small hydropower technology in China is just appropriate to the technical level of our Africa countries. HRC has strong expertise in SHP training, design, consultation and complete equipment supply. I sincerely hope that HRC will continue to hold the small hydropower training workshop to help the development of the SHP resources in African countries.”

During the period of training workshop, a series of SHP technical-cooperation discussions have been conducted with the participants from Rwanda, Congo, R.D.Congo, Mali, Niger, Guinea, etc.. In these discussions, their demand and suggestions have been explored related to the SHP development in their own countries, and HRC expressed the willingness to provide assistance to the SHP exploitation in these countries in terms of either SHP planning, training, designing or equipment supply. Many participants provided their national future development plan on SHP to HRC for cooperative reference, and expressed that they would push forward the cooperation between HRC and their home countries, disseminating China s SHP technology and experience.

Under the powerful support of Chinese Ministry of Water Resources, HRC upgraded its hotel and training facilities in 2004. Nearly all the participants were satisfied.

Private Sector Participation in Electricity Generation and Distribution

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Abstract

In terms of hydropower resources in the country, Nepal ranks second in the world. But it has not acted seriously in terms of utilization. The effort began from the Rana days when they ruled the country for more than century. For energy, unfortunately, the country has at times sought thermal source rather than hydropower.

For energy needs, it first depended upon foreign aid in the earlier dates. As late as in the '60s, it depended upon such assistance rather than developing its own. So much so, that it imported electrical power from neighbouring country. Later, it was developed both under foreign aid as well the multilateral assistance and loan. The electricity generation gradually became more and more costly. Only later, genuine private sectors have joined the energy market. But the terms and conditions have not always been in the national interest. There is a wide variation in cost of energy under different conditions of power development in the country, from the cheapest to the costliest. Both for generation and distribution, Nepal Electric Corporation should no longer continue its monopoly. Private sector should be promoted given more role to play for economy and operation.

The paper discusses the different options available and practised in Nepal.

Introduction

Nepal is endowed with rich water resources. The topography of the country stretches from the Mt. Everest *(Sagarmatha)* 8800 m to 25m across a width of 150 km. Number of rivers mostly originate from the Himalayas and go down to India in the south. A number of sites are suitable for hydro-power generation. It could be one river with a number of hydropower sites. For example, Kulekhani project under Japanese assistance has been gradually further developed for two such sites. Khimti hydropower developed by Norway is also finding additional sites few kilometers away. The alternative sites are there in the Seti River. Having such sites in the river offer many advantages.

Nepal has hydropower potential of 84,000 MW and economically exploitable is 34,000 MW. In the beginning, the effort for hydropower utilization was only at the government level. But many friendly countries and later private sector have come up for exploration and utilization. Their degrees of interest and efforts were different. The nation itself must be serious in the matter of national interest.

Early Power

The exploitation of hydropower resource in Nepal started in 1911 with the 500 kW Phirping Power House in the Kathmandu Valley. The first external assistance for hydropower development was from USSR and 640 kW Panauti Hydropower was built in Panauti for Kathmandu. The increasing needs in the capital were later fulfilled by diesel generators. Much later in 1972, the 10,000 kW hydropower was developed under the Chinese aid at Lamo Sanghu on way to the Tibetan border in the North. Later several international government and international agencies came in for hydropower development in Nepal. Kulekhani (stage 1, 2 and now 3) and Marsyangdi projects were under Japanese and Germany under multi lateral assistance with a number of strings attached and grace period varying from 23 to 40 years.

Agencies for generation/distribution

Power generation and distribution was under the Department of Electricity of His Majesty's Government (HMG). Later, Nepal Electricity Corporation (NEC), a 100% government-owned agency, took up the work later. *Ts service area was confined the central development region of the country*. Eastern Electricity Corporation was also formed in the early '70s and it worked for some years in the Eastern Nepal as there was no national grid developed then to link with the rest. Later that too was amalgamated into NEC. The Corporation had taken over Morang Hydro in Biratnagar. Similarly other private sector companies in the western region were taken over. Both the Department and NEC undertook power generation, transmission and distribution works for some time. National grid, linking the East and West, was gradually developed all along the East–West (Mahendra) Highway of the country. Later NEC was reorganized as Nepal Electricity Authority (NEA), a lesser bureaucratic organization for generation, transmission and distribution of energy. The services could be undertaken by others too. But only toward generation, some agencies have joined in the private sector. Butwal Power Company has taken up distribution and transmission in selected area. It has electrifies 15,000 households.

Inconsistent Generation Efforts

The energy needs go on increasing as it is provided to larger section of people as well as for industrial and others consumption needs. There may be a big leap if there is a significant growth of energy intensive industries. The biggest set back was when the World Bank dropped the 400 MW Arun III with reservations such as “preservation of aquatic life in the Himalayas”.

When the supply side lagged behind, and demand was growing at double digit rate, and at a time, Nepal fulfilled its need even by importing electricity from India though the agreement was to supply to each other from convenient locations. But Nepal was, in net terms, the importer until 2000 after which Nepal had enough energy from the Kali Gandaki ‘A’ project. It was increasingly felt that NEC alone should not be depended on generation and distribution.

Electricity from Private Sector

NEA has removed the limit on the amount of power that can be purchased from Nepalese hydropower companies. Earlier, it would buy only up to 50 MW from private parties. Now NEA will purchase all electricity produced by Nepalese companies. But NEA has not changed the rate of power it purchases from Nepalese companies. It is Rs 3 and Rs 4.25 per unit in the wet and dry seasons respectively. This rate is not valid for international companies.

NEA pays exorbitant electricity-price to Independent Power Producers (IPP) as some hydropower experts agree. With inflation over the years, NEA now pays seven cents per unit to Khimti and Bhote Koshi projects. The authority does not even earn back from its customers what it spends to plug into their homes electricity from the two IPPs. The rate is gets jacked up to 11 cents adding technical loss, transmission and distribution costs. That translates into eight rupees per unit. Now compare what it charges to its clients for the same electricity: not even seven rupees per unit. The NEA incurred loss of more than one billion dollars in power purchase from private producers, Khimti and Bhote Koshi, in the fiscal year 2000-2001. NEA had bought power worth Rs. 2.3 billion that year but turnover from the electricity was only Rs one billion. Currently 42 percent of NEA's income goes to these two companies. In contrast, the power from the 20 MW Chilime and 3 MW Piluwa Khola, both of which have been constructed by local investment, is much cheaper.

NEA's average electricity tariff is Rs. 6.81 per unit, which is among the highest in the world. This is mainly because of high cost of construction and the high price of power purchased from Khimti and Bhote Kosi power projects, the two IPPs, which has to be paid for in dollars.

Energy For Export

From western to eastern regions of the country, the rivers originate from the Himalayas in the North and flow down to *terai* (plains) in the south and meet the Ganges of India. Nepal shares border with India in the north, east and south. The adjoining Indian states of Uttar Pradesh, the newly-formed Uttaranchal and Bihar have frequent power cuts due to shortage of power. Both in Bangladesh and India, additional power is in demand as the following figures say. The West Zone of Bangladesh wants additional power. Several other states of India also are short of power. The power shortage in neighbouring states of India, Bihar and UP are very acute.

Similarly, the West Zone of Bangladesh is considered to be in deficit of electricity as shown below:

Currently, its requirements are met by thermoelectric plants based on imported fuel and supply from the indigenous gas plants transmitted over the 220 kV East-West Interconnection. During the next decade, Bangladesh is likely to face deficit of up to 1,800 MW. There will be a shortage of 600 MW in the West Zone. The deficits in the coming days are shown in the following table.

Cost Effective Projects

The power needs of the region may be fulfilled by Nepal. Generation works may be taken up

Projected Capacity (MW) Deficits

Year	2000	2005	2010	2015	2020
Total	500	1,100	1,800	3,100	4,900
West Zone	150	340	600	1,000	1,600

be NEA or other agencies in national/ international agencies in the private sector. Past experience of hydropower development in Nepal and India has shown that Nepalese projects are more cost effective. A comparative capital cost study for earlier projects in the two countries are given below:

Hydro Project Capital Costs in $/kW

Projects	Capital Cost	Projects	Capital Cost
India			
Tehri (UP)	1,111	Chamera-II (HP)	2,638
Nathpa Jhakri (HP)	1,336	Uri (J&K)	1,816
Dulhasti (J&K)	1,784	Dhauliganga (UP)	1,501
Nepal			
Andhi Khola (ST)	2,143	Upper Karnali (PROR)	1,351
Arun-3 (PROR)	1,431	Lower Arun (PROR)	1,593
Dudh-Koshi-1 (ST)	2,096	Seti River-3	1,420
Kali Gandaki-2 (ST)	1,318	Upper Arun (PROR)	1,444
Budhi Gandaki (ST)	1,352		

- Indian Project Cost estimates from TERI< exchange rate at 36 Rs./ kW, Nepalese cost estimates from Nepal Master Plan, The projects are excluding IDC and transmission costs.

Source: Nepal, Power Sector Development Strategy (Draft Report), The World Bank, June 7, 1999

Delaying for the Right Time

Several prominent sites are available in Nepalese rivers for hydropower development and they are suitable for in-country consumption as well as for export promotion. The sites may wait for the right time when the developers, Nepalese or others, may be interested.

Some sites have been selected by hydropower developers and start the preliminary works later. They have stopped taking further interests or the works are handicapped for several reasons delaying its completion and thus affecting the national development. In others, there are so many options that the country cannot decide, which options to take up for implementation.

Considering the present condition of poor availability of power for specific region in the country, if those sites are used for lesser power development or selecting the one for power development at a site damaging the full potentials of those sites, their utility for further exploitation may be doomed for ever.

Indian Co-operation Delayed

India has helped Nepal through several hydro power projects. In some cases, the power came as "by-products" of irrigation projects such as on the Koshi and the Gandaki rivers. The hydropower as by-products in the two water projects failed after ten years, due to excessive sandings and there have been no effort to revive them. Both of them have been closed now but the irrigation works continue. The projects serve larger area in India than in Nepal.

India has signed several co-operation projects but in most of them, timely implementations are still awaited. It has very ambitiously taken up some projects in which other promoters had taken interest but were delaying. The Pancheswar Barrage under the Mahakali Treaty (named after the Mahakali River in western Nepal) was to produce 6,480 MW of energy. Under the treaty, it was to be completed in 8 years. But nothing concrete has taken shape yet.

Indian interest in three river projects are illustrated below. They have yet to see the light of day. Three examples may be quoted:

a. The Budhi Gandaki Project

The Budhi Gandaki Project was proposed in the *Panchayat* days (1961-1990) in the country. It was agreed together with Tanakpur Project in December 6, 1991 when the Nepalese Prime Minister made a goodwill visit to India. The project was to be started in 1994. It was removed from the list in 1995 and added again in 2002 and that India will do the designing work.The concrete work for power is a matter of distant future.

b. The West Seti Project

In 1992, on behalf of the French Government, a French company had completed and submitted study of West Seti Hydroelectric Project. It capacity will be 360 MW. The government, gave the development license to Snowy Mountain Engineering Company (SMEC) of Australia in 1994. The agreement with the Department of Electricity Development (DOED) and the Company had provision of 10% generated power to Nepal. The second agreement was made with government in 1997. The capacity was increased to 750 MW. In the revised accord SMEC had now not to offer power but pay the revenue of the 10 per cent power. The company had to provide financial management details by December 2002. The company applied to extend the deadline for the fifth time just before the expiry of the deadline.

Power Trading Corporation (PTC) of India nodded to purchase the electricity at per unit price of 5.12 US cent. The price was revised after PTC in the 2000 declined to pay the earlier quoted per unit price of 7 US cents. In the time that elapsed between 1994 and 2004, several new power projects, large and small, have come up.

The delay in the private sector project was taken up by the Australian government. In January end 2004, the CEO Sylvain Jean Leveaque of the Singapore-based French humanitarian trust came to Nepal to reactivate Upper Karnali project. The 300 MW project cost US$ 470 million.

The company, Elysee Frontiere, is working in association with a local private company to resurrect the project. The development came 27 months after the French Trust signed the PPA with the NEA. Under the agreement, signed in October 2001, NEA would buy 50 per cent of the power at Rs 1.45 per unit, while the price of the remaining 50 per cent was agreed at Rs 2.90. (US$ 1=Rs 74) The project was already gone as the Elysee Frontiere board held in London in June 2002 had already cancelled the US$ 500 million fund allocated for Upper Karnali.

India's National Hydropower Corporation (NHPC) officers arrived to prepare the groundwork for the development of Upper Karnali, nearly five months after Nepal and India agreed to jointly develop the hydroelectric project. Hong Kong-based Hong Kong Shanghai Bank (HSBC) had already issued US$ 250 million worth bank guarantee for the venture in Nepal. On February 2004, the NEA and NHPC agreed to jointly develop the 300 MW Karnali Hydro-electricity Project. In the joint venture company, India would put in 49 percent of the total estimated cost of US$500 million. The two sides had to prepare the Detailed Project Report (DPR). India will buy the power generated from Upper Karnali.

As per the latest development (November 2004), China Machinery and Equipment Export and Import Corporation (CEMEC) and Snowy Mountain Engineering Corporation (SMEC) with 70% and 30% investment will develop the project at a cost of Rs 6700 million. By the middle of 2005, the construction work will start. The government will get 2% royalty and 10% of the 750 MW power. Power Trade Corporation of India will buy the power at 4.95 cent per KW. The rate is half the prevalent rate in Nepal.

c. The Upper Karnali Project

In 1998, the World Bank did the feasibility study through Delta Pacific Consortium. An agreement was signed by the Ministry of Water Resources (MoWR) and the Consortium in 2000. The license was issued by the Ministry to the Ellece Frontiers Company had offered 30% share to NEA. The license ended on January, 2002. Later when the Nepalese Prime Minister was on visit to India in August 2002, the project was offered to India "as per the understanding reached in 1999 for the medium size projects". This was to be a joint project on NHPC and NEA. But nothing concrete is heard there after.

So far, hydropower development efforts have been on government-to-government level. There is provision for other sort of arrangement. State as well as semi-government organization can enter into hydropower development projects. Several private companies are generating power in India. But perhaps they have to seek permission from Centre for seeking such an agreements with foreign bodies.

Energy Purchase Price

At present, the energy purchase price is Rs.4.2 for dry season and Rs.3.00 for the wet season for small hydro (<10MW), whereas for medium and large hydro projects it is being fixed on the basis of bargaining. NEA has already bought 121 MW of electricity through PPA with private sector, including 5 MW Mailun Khola, 10 MW Langtang Khola, 2.6 MW Sunkoshi and 1 MW Barmachi.

Hydropower Projects 2002/3

NEA has 10 major hydro Projects (existing) under public sector NEA: Sunkosi, Trishuli, Devighat, Gandak, Kulekhani-I, Kulekhani-II, Marysnagdi, Puwa Khola, Modi Khola and Kali Gandaki "A" with a total generation capacity of 389,150 kW.

There are six projects under private sector. NEA has signed power purchase agreements (PPA) on Andhi Khola (5,100 kW) and Jhimruk (12,300 kW) of BPC. Khimti Khola 6(0,000 kW) and Bhote Koshi (36,000 kW). Chilime is of 20,000 kW. Sange Khola and Indrawati are of 183 kW and 7500 kW respectively. According to NEA, Three projects of a total of 7,100 kW is in progress. Preliminary works for 6 projects of a total of 31,844 kW is in progress in fiscal year 2002/3. In the private sector, Andhi Khola (5.1 MW) and Jhimruk (12 MW) are under Butwal Power Company (BPC), Khimti Khola under Himal Power Limited (HPL), Bhote Kosi under Bhote Kosi Power Company (BKPC), Indrawati-III under National Hydro Power Company (NHPC) and Sange Khola under Sange Hydro Power

Company (Sange HP).

Private Sector investment in Hydropower

Electricity was a government business until the promulgation on Electricity Act 2049 which paved the way for private Sector for investment. Under the Electricity Act, one could get license to "generate, transmit and distribute electricity for 50 years". The *"Build, Own, Operate and Transfer"* (BOOT) agreements in the '90s paved the way for Khimti and Bhote Koshi Projects. In the 12 year period, Khimti (60 MW), Bhote Kosi (36 MW), Chilime (20 MW), Piluwa (3 MW), Indrawati (7 MW), Syange (183 MW) etc are generating and distributing hydropower. Different project of 14 MW are under construction. 46 projects of 95 MW got the license and are in process to get the studied, power purchase agreement and investment.

Nepali Banks have spent about Rs 4 billion and investment from the IPPs is estimated at Rs 3 billion. Small Hydropower Policy 1998. The contribution of IPPs in power generation was 35% in 2002-03. The growth of SHPs is attributed to flexibility in investment by local financers, since there is unscrupulous conditionality like the loan assistance from the multilateral banks or donors.

The contribution of IPPs in power generation was 35% in 2002-03. The growth of SHPs is attributed to flexibility in investment by local financers, since there is unscrupulous conditionality like the loan assistance from the multi-lateral banks or donors. Nepali Banks have spent about Rs 4 billion and investment from the IPPs is estimated at Rs 3 billion. They are gradually coming up for larger projects. Chilime projects, for one, is started by the employees of NEA. The private sector is thus coming up both for generation and distribution.

NEA has already bought 121 MW of electricity through PPA with private sector, including 5 MW Mailun Khola, 10 MW Langtang Khola, 2.6 MW Sunkoshi and 1 MW Barmachi.

Foreign Investment in First hydropower projects

Bhote Kosi and Khimti are the first two hydropower projects with foreign investment. But the companies could not work smoothly. The 60 MW Khimti hydropower project has 87% investment from Norway and 13 % Nepalese Investment. Permission for construction was granted in 1993 and agreement for sales in 1994. Commercial production in June 2000. The Project will run solely for the first 20 years and jointly for the extra 30 years and later handed over to HMG. The $100 million Bhote Koshi hydropower project started in 1993 and went on stream in 2000. The power plant is near the Chinese border. It has a capacity of 36 MW, with power of 246 GWh/year. It ended up generating 52 MW by the time it was built. The agreement also quoted 6% rise in the price every year. The power purchase agreements for the two projects were Rs 5.35 and Rs 5.19 respectively. The effective rate, considering transmission cost and leakages was Rs 7.69 and Rs 7.35 respectively.

Dispute in Bhote Kosi Hydropower

The power purchase agreement between Bhote Kosi and the NEA was to buy only 36 MW at Rs 5.5 per unit. But the company started billing for 16 MW of extra power, amounting to nearly $100,000 per month more than stipulated in the agreement. There wouldn't be anything wrong with that had the NEA not already got excess capacity during the monsoon through other sources and at a cheaper rate. It would therefore end up paying more than originally agreed for power it won't be able to sell to consumers.

The NEA is under pressure from the Texas-based Panda Energy of the USA. The US investors threatened to scrap the US textile quota through the Senate and to stop World Bank aid to Nepal. In March 2003, Panda offered option to buy the project for $100 million plus interest owed to financiers with a 30 percent premium.

The Department of Electricity Development (DoED) has decided in February 2004 to initiate action against the Bhote Koshi Power Company. The company will have to pay the fine in three instalments—Rs 900,000 every year. By the end of November 2004, BPC proposed a new PPA to the government for mutual consent. Under this, the PPA will be for 45 MW and not 36 MW, there will no annual escalation in power purchase agreement, and government will pay $3.6 million for the energy sold to NEA in the last three years.

The dispute has caused further delay in the promotion of foreign projects. Several projects are in the pipeline.

Norway for Upper Tamakoshi

Norway, one of the main supporters of hydropower development of Nepal, has offered its assistance in the 250 MW hydropower project on Upper Tamakoshi in Dolakha district and presented a detailed feasibility study and the design. The pre-feasibility study carried by NEA found this project to be the cheapest of all the other hydropower schemes. The total investment of the project is US$ 227 million (NRs. 17 billion) i.e., 2.5 cents per unit. This estimate includes construction of 100 km of 220 kV Transmission line and 70 km road to the project site. Construction time for the project is estimated to be 7 years. The project could be one of the cheapest hydro projects in Nepal, requiring US$ 1100 per kW.

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Small Hydro

With rich potential, Nepal long dreamt of large hydropower from its 6,000 large and small rivers. As seen, the international hydropower developers have their own conditions and priorities and demand high price for development. It is high time, the country explored its own potentials. Small and micro hydro can play a pivotal role in the socio-economic upliftment of rural hilly areas, which constitute more than 75% of the country. There is enormous potential for the development of small hydropower and the in-house capability to build these small hydro plants is already available within the country.

Small Hydropower Plants (SHP) of up to 100 kW have been delicensed from 1984 to encourage private sector participation in rural electrification. There are 1,750 small hydropower plants of 6,540 kW and 1,750 plants are to be developed in fiscal year 2004/05.

Performance of SHPs have been satisfactory. Assistance from different international agencies are available for small hydropower development projects: For Peltric Sets i) up to 3kW, grant of Rs 55,000 per kW and ii) for 3 kW-100 kW Rs 70,000 per kW. They are also encouraged to use energy efficient lamps so that electricity reaches to more and more people. In the Rural Electrification sector, His Majesty's Government (HMG) gives grants for projects of up to 500 kW. 5,000 kW of energy is produced under this programme and it has benefited 35,000 families.

Several villages are away from the grid lines and they may not expect power in the normal course. Private entrepreneurs and the village communities are themselves coming up for SHPs. There are some interesting records. After the establishment of Energy Support Assistance Support (ESAP) the subsidy policy as well as the installation process have been revised. Performance of SHPs have been satisfactory. Assistance from different international agencies are available for small hydropower development projects: For Peltric Sets up to 3kW, grant of Rs 55,000 per kW and for 3 kW-100 kW Rs 70,000 per kW. They are also encouraged to use energy efficient lamps so that electricity reaches to more and more people. Subsidy at the rate of Rs 27,000 per kW for more than five-days walking distance, Rs 8,750 for 2 to 5 days of walking distance. 50% of Rehabilitation cost of the project up to the estimated cost to Rs 53,000 per kW is being provided.

The Rural Electrification sector, HMG gives grants for projects of up to 500 kW. 5,000 kW of energy is produced under this programme and it has benefited 35,000 families. Micro-hydro (MH) technology has been disseminated in about 60 districts of Nepal. About 15 companies have installed these plants during the past three and half decades. In addition to these companies there are several government, semi-government, non-government organizations involved in dissemination of micro-hydro power in the country. Turbines for milling purpose accounts for over 80 percent of the existing micro-hydro schemes in Nepal. These schemes are used in a range of agro-processing machines such as rice huller, grinder and oil expeller.

Rural electrification has proved to be very challenging and expensive. Providing electricity to one household requires Rs. 15,000 to 30,000. The NEA charges a subsidised rate of Rs. 4 per unit from clients who consume less than 20 units of electricity. Currently about 75 percent of the NEA's clients use less than 20 units. As a result, the country is not earning a profit from such hydropower projects. One the other hand, Nepal imports 360 million litres of kerosene per year and sells it at a loss of Rs. 8 per litre. The government thus looses Rs. 2.88 billion per year on kerosene subsidy, which comes out to be Rs. 823 per household.

It is questionable that the five NGOs in the five development regions of the country is sufficient for the promotion of micro-hydro in the country. In order to arrange the HMG/N and ESAP's fund for subsidy an interim Rural Energy Fund is established and it is managed by Alternative Energy Promotion Centre (AEPC) and ESAP.

Nepal has developed national grid along the Mahendra (East-West) Highway now. But getting electrical energy from the national grid at all places of the country is not desirable specially when connection is sought for sparcely populated areas at scattered hills. For such aeas, it may be desirable to have isolated centres of power. A number of villages, mostly combined, have opted for isolated centres. Initiatives at the villagers level have resulted in a number of such hydroelectric enterprises throughout the country.

Power for Remote Areas

Although it has been 90 years since the country got electricity, as of present, 40 percent of Nepal's households have access to electricity. For the rest of areas, for lighting purposes they are still depend upon costly kerosene which is costlier to transport into hilly areas.

Projects of less than 10 MW is designated as S*mall Hydros* as per Nepal Law. For a 500 MW power system the small hydro will not create any problem of overproduction. On the contrary, it may serve as a reserve for the system also. So any number of small hydro, which are practically implementable, should be welcomed. In the 10th Five-year Plan, period small hydro power plants have been included to be implemented in a massive scale (27 plants = 57 MW). This is a starting period for the IPPs to invest in hydropower sector.

There are 9 grid-connected units: Phirping (Not in operation), Panauti, Sundarijal, Phewa and Seti (Pokhara), Tinau (Butwal), Baglung Tatopani and Chatara. The capacity range from 200 kW to 3,200 kW. NEA has 33 existing (isolated) SHPs of 6,416 kW capacity, of which 12 SHPs are leased to the private sector. Of them, Salleri and Namche are owned by the private sector. Only Kalikot and Jhupra (Surkhet) are of 500 kW and 345 kW capacity. All others are of less than 300 kW capacity. Salleri Project is under joint venture company SCECO. Management of this plant is based on peoples' participation. The local people also have shares in this company along with NEA and Swiss Organization. On way to Mount Everest, the Namche Power Plant is managed by KBC, a private company.

Several villages are away from the grid lines and they may not expect power in the normal course. Private entrepreneurs and the village communities are themselves coming up for SHPs. There are some interesting records.

A. Syange Hydropower

Syange hydropower is the cheapest hydro electricity in Nepal. Generation cost of this 100 kW hydropower is less than Rs. 0.1 million per kW where as the large Kali Gandaki 'A' project is costing over Rs. 0.3 million per kW. The Plant was developed at a total cost of Rs. 18 million with joint investment of Rs 6. 5 million from local people and the Lumjung Electric Development Company (LEDCO) and a Rs. 10.5 million loan from Machhapuchhre Bank of Pokhara. This is an example to show that local capital and local manpower can be effectively combined to build small and inexpensive hydropower plants.

LEDCO at Ilampokhari VDC in eastern Nepal has project capacity 20 kW. Installed capacity of the company is 11 kW. The project cost is Rs 3 million. The company provides 11 watt CFL lamps (equivalent to 40 watt lamp) to the users. The facility is availed by 200 families. Per family cost for lighting is Rs 20 per month. The project is supported by DANIDA (Danish International Development Agency). Similarly, Jhankre Rural Electrification and Development Project (Second Phase) reached 4,400 households with population of 27,000. It got project assistance from NORAD, a development agency of Norway. The assistance was up to 80%, HPL provided the remaining 20%. The project makes a net profit per year of Rs 3.5 million. Electric tariff by the Jhankre Electif Project from the first year, distribution system from second year, Electric House partially from the third year. In the fourth year the project. was completed.

B. The Energy Valley (Urja Upatyaka)

The Rural Energy Development Program (REDP) is developing Baglung District in the Western Development Region of the country, formerly known as the District of Suspension Bridges, now *Urja Upatyaka* under the framework of Community Mobilization (CO). The program was initiated in September 1997.

So far, 109 COs (50 males and 59 females COs) have been formed. It has the following projects and the number of households: Theule Khola (stream) 24 kW, 290; Kalun Khola 22 kW, 230; Urja Khola 26 kW, 250; a 8kW a 20 kW, and a 15 kW in Paiyun VDC, 70, 200 and 150. The 100 m from the tail-water of Urja Khola generates 8 kW and benefits 100 households. The Rural Electricity is generated by the community people. There is a water turbine for agro-processing gives 6 kW for 32 households and Solar Home Systems (SHS). Rural bakery, poultry, hotels and restaurants, photo studios etc are sprouting. Women's drudgery has reduced. Theyhave more time for IG as well as social activities. Schools have introduced computer classes. In 120 ha of barren land now there are 194,000 seedlings have been planted. 450 ICS have been installed. 18 toilet-attached biogas have been installed.

C. High Altitude Micro-Hydel Project

On October 2003, the micro hydro project at the highest place in the world was completed in the region of Tsho Rolpa situated in Rolwaling Valley of Dolakha District in central Nepal. The project generates 14 kW of electricity from the Chhoroipa glacier at 4,580 metres in Gaurishankar VDC. Earlier, a 20 kW project was built at Therangphedi at 4,500 meters. The Tsho Rolpa glacier lake in Nepal was identified by scientists as a potential threat for an outburst stands. The glacier lake had a serious outburst in 1999.

The Department of Hydrology and Mateorology (DOHM) is pushing for a seven-month extension on the four-year Tsho Rolpa Glacier Lake Outburst Flood Risk Reduction Project (TRGRRP) after it ended in December 2002. The Government of Netherlands agreed to fund the extension of the project, which included a hydropower plant with a capacity of 15 kilowatts and survey of the surrounding lake. The microhydro plant opens up potential tourism opportunities. Tsho Rolpa Lake is also a trekking route. Trekkers will be able to halt at our base, see the achievements of the project and at the same time be able to benefit electricity produced in an environmentally friendly manner. The main objective of the four-year project was to reduce the water level sufficiently to immediately and tangibly reduce the risk of breach forming in the natural moraine dam, by the construction of an open channel. Lowering the lake level has increased the freeboard of the dam, decreased the hydrostatic pressure within the moraine and reduced the volume of water available to form a potential Glacier Lake Outburst Flood (GLOF) by 20 percent.

D. Free Electricity Now

30 families in Kerung Village in Solukhumbu district invested in a 2 kW micro-hydro plant. A few years ago, residents of Kerung, a village of 12-hour walk from the district headquarters, collected Rs. 5,000 each family and borrowed Rs 315,000 from a bank to construct the micro-hydro plant at the local Bagam Khola. Initially they sold the electricity to all households at the government rate and as the loan have been paid off, each house gets one light-point free. They have sold excess electricity to houses in the neighbouring village and paid the debt and now enjoy free electricity.

E. Water Pipe for Electricity

The Nete VDC of Gulmi District use 750 Watt of electricity generated out of the water pipe that passes through the village. The 4-way tank and pen stock pipes were used for this purpose. It received Rs 68,000 for this purpose from GARDEP Project and the rest from the villagers.

User Groups to Manage Rural Electricity Supply

HMG is encouraging the local Users Group. Eighteen users' groups have signed agreements with the NEA to manage distribution of electricity in rural areas. The NEA approved the application of 25 users' groups from across the country seeking to manage and distribute electricity. According to the Community Rural Electrification Department of NEA, over 170 users' groups, cooperatives and NGOs have so far applied for managing distribution of electricity in villages. NEA board last year approved the Community Electricity Distribution Regulation, 2003 allowing users' groups, cooperatives and NGOs to manage electricity distribution. The government is entitled to invest funds amounting to 80 per cent of the rural electrification cost initially, while the local organisations should have a share of 20 per cent as a counter fund. Enjoying the ownership of operation and maintenance of the electricity distribution system locally, these organisations are entitled to act as fully autonomous institutions.

Near Kathmandu, South Lalitpur Rural Electricity Co-operative Society, in co-ordination with NEA, is vying for distribution of electricity to the 19 VDCs. Just five percent of the country's rural population and 18 percent of the total population enjoys electricity. The co-operative society collected Rs 164.4 million and the government provided Rs 230.8 million.

International Concern

The UN Symposium on Hydropower and Sustainable Development in Beijing on October 27-29, 2004 passed the 'Beijing Declaration' which called for tangible action to help developing countries finance sustainable hydropower through loans and grants. It recognizes the World Bank and regional development banks' plans to re-engage, but called for similar commitments from bilateral agencies to assist in the development of affordable and sustainable hydropower. It also urged developing-country governments to create a favourable environment for co-financing from private investors, including strengthening "a transparent regulatory framework". As seen, the declaration is very pertinent for hydropower development in Nepal.

Presentation at the Closing Ceremony of TCDC Training Workshop on SHP for Asia-Pacific

Zhu Xiaozhang, Honorary Director of HRC

Dear Participants, Colleagues :

Our memorable training workshop is going to an end now. It is my pleasure to send a remark on this grand closing ceremony. First of all, I'd like to express my warm congratulations to the full success of the workshop which has been achieved under joint effort of HRC staff and all of you the distinguished participants. Now, I would like to talk about 5 points in the followings :

1. The success of the workshop once again proves the deep insight or philosophy delivered by a senior official Mr. Tanaka from UNIDO, on the first Training Workshop on Small Hydropower for the Asia-Pacific in 1983 at HRC. (Unfortunately, Mr.Tanaka passed away several years ago). Upon analysis of the technological dependency of the developing to the developed countries and the widening technology gap between the two groups of countries, he pointed out that well-organized training workshop would be an answer to reduce the gap. But on the other hand, in many cases the developing countries do have such technological capability and capacity, and it is a matter of how these existing capabilities could be effectively mobilized to serve the needs of the countries. And it is more often than not, a problem of "self-confidence" that could motivate an effective contribution of such "technical capabilities" to serve the purpose. It is for this reason that UNIDO has preferred to call the training activities not simply a " training course " but a "training workshop " with emphasis on the latter word "workshop". It is the active participation of the individuals in the excises, the debates, the thinking process and the subsequent mapping out of an action plan (or follow-up cooperation activities) that would provide the participants with that " self-confidence " to recognize that after all everybody thinks the same way and acts the same way, and there is little difference in the " capabilities " except " accumulated experience ." Although this statement was made more than 20 years ago, our present workshop has further vividly reflected the correctness of this inference. As the technological capabilities and capacity have further been improved in most developing countries, this workshop type event is likely to be more proper rather than a simple training course.

2.In addition to our well-prepared technical materials on the basis of China's experience of small hydropower development and well-organized workshop in both presenting the papers in the room and effectively implementing the on-site visit to generation plants and equipment manufacturers, the country report presentation and bilateral cooperation meetings were successively held. To my personal feeling, the participants' presentations are all well-prepared and well-presented which gave deep impression to all of us. Not only comprehensive information and latest status of small hydropower development and even electric industry's development in the respective countries have been delivered but also some specific experiences with respect to small hydropower development were offered in the presentation, which were of course valuable and helpful to all of us. For example, the Indian experience of private participation in the SHP development and their innovative mechanism for power sales and purchase activities is very inspirational to us. I'd suggest all the participants to prepare your own papers in wordings on the basis of your Power Point version for HRC to publicize successively on its quarterly journal << SHP-NEWS>>.

3.Throughout the whole period of the workshop, cordial and friendly atmosphere were filled in every event, animated discussions with substantial contents mostly occurred, and cooperative and constructive spirit were shown both in the bilateral meetings and in the classroom discussions as well. Here, I'd especially express our appreciation and thankfulness to the class monitor and chairman of the country report presentation for his effective effort and contribution to the co-organization of the workshop with HRC.

4. We have a saying in China recently expressing Chinese peoples' best wishes to build a harmonious world with people from other countries and regions as was given by the 2008 Olympic Games preparation. May be we can also say that in our SHP sector, we SHP people have also set up a harmonious circle which shows both friendship, mutual learning and cooperation among peoples from different countries with different faces, cultural and religious background. All these further signify the existence and role of the " SHP- family " which was usually awarded to HRC by international SHP people. The great Chinese ancient philosopher Confucius said: " In human relationship, a gentleman seeks harmony but not uniformity " which taught us that " harmony without sameness is an important principle in the development of all social affairs and relationships and in guiding people's conduct and behaviors ". I was especially impressed when I was told that our participants have had an up-close discussion with college students here which had further gave you an opportunity to exchange not SHP professional knowledge but broad cultural ideas for furthering your understanding of Chinese people in a wider sense. Hope that all the activities you have engaged in China will be helpful to build up " confidence " in setting up cooperation with China and for you to act as a bridge of mutual cooperation between our countries.

5.Last but not least, although we all know that the S-S cooperation is now undergoing an expansion from TCDC to ECDC, but I'd still stress that these should also be further understood of its expansion to trade and investment. So, the prospect of our future cooperation could be summarized as "T+E+T+I ". We look forward to hearing from you of any follow-up event proposals after going back home. We will of course do our best to offer our contribution in promoting the SHP development worldwide, including your particular country.

Thank you.

A Summary of 2005 SHP Training Workshop for Asia-Pacific Countries

The 2005 TCDC (Technical Cooperation among Developing Countries) Training Workshop on SHP for Asia-Pacific Countries was held from 20 Oct to 28 Nov 2005 by Hangzhou Regional Centre for Small Hydro Power (HRC). Attended altogether 30 participants from 16 countries of Asia, Africa, Eastern Europe and Latin America. At the closing, Mr. Zhu, the honorary director and founder of HRC, Ms. Cheng, deputy director of HRC issued the certificates to the participants.

This training workshop which is the 40th international SHP training workshop conducted by HRC was sponsored by Chinese Ministry of Commerce, as one of the technical collaborative projects among the developing countries.

In addition to classroom lectures, study tours were arranged to Shaoxing, Shengzhou, Linhai, Wenzhou, Haiyan, Ningbo, Nanjing and Shanghai, where the participants felt to have benefited much. In Shaoxing, Shengzhou, Xinchang and Linhai, they visited some SHP stations of various development types including the rubber dam and equipment manufacturers. Visits were paid to Linhai Machinery Plant and Linhai Electric Machine Plant where participants were able to see the whole process of the hydropower equipment manufacturing. In Wenzhou, participants were excited to visit the big private company Chint Corporation Ltd which has been fast growing in the recent years. Participants went to Ningbo, visiting a pumped storage station with installed capacity of 80 MW. This station designed by HRC in the past few years was put into operation at the end of 1997. In Xiaoshan, visits were made to Hangzhou Dalu Electric Equipment Co. Ltd and Hangzhou Sanhe Electric Controlling Co. Ltd. Also, days were spent in Nanjing and Shanghai —the largest city and port of China. In Nanjing, participants paid visit to Guodian Nanjing Automation Co. Ltd and Tiexinqiao Hydraulic Experimental Base which is China's largest hydraulic experimental base. There, participants enjoyed watching spectacular fireworks. In the coastal areas of China, participants discovered the tremendous changes in China after implementing opening and reforming policy. In Haiyan, participants were delighted to be able to visit one of China's nuclear power plants — Qinshan Nuclear Power Company which is the first nuclear power station designed, constructed, tested and operated by the Chinese.

The questionnaires from the participants show that rate of their satisfaction for this SHP training workshop reaches 100%.

Monitor, the Indian participant Mr.Yeptho pointed out at the closing ceremony, "We really appreciate and highly impressed not only for the fabulous facilities provided to us, but also for your sincere efforts to make all of us feel at home during our stay. The training program was definitely the world class with highly customized subject methods fitting each and every participant from different background. The training program was professionally managed with well balanced course materials, time distributions and other curricular activities."

Entrusted by Chinese Ministries of Water Resources, Commerce, Science & Technology, UNDP, UNIDO, ILO, FAO and etc, HRC has run around 60 SHP related training workshops for 3000 participants, of whom over 700 of them came from over 70 countries.

This training workshop has the following features:

1. More study tours were arranged, including the visits to Hangzhou Dalu Electric Equipment Co.Ltd, Hangzhou Sanhe Electric-controlled Equipment Co. Ltd, the fast developing and vigorous private enterprises in Zhejiang province, as well as Guodian Nanjing Automation Co. Ltd. and HRC Laboratory, etc. After the visits, especially during the discussions on SHP international cooperation, many participants expressed their intention to order the governors, the turbines and/or the TC operators.

2. In the view of the specific conditions on SHP exploration in developing countries, we made corresponding adjustment to the teaching material and the curriculum in time, ensuring HRC's presentations more appropriate to the situation of developing countries. Meanwhile, due to the environmental issues, the international society pays more and more attention to environmental protection currently, so we also offered a topic on "Environment vs Energy", which was highly appreciated by the participants and they were extremely active in inquiry and discussion on environmental protection issues. Considering that most participants were also interested in items related to SHP investment and financing, we specially arranged a topic on "SHP" Financing".

3. In order to meet the participants' demands to understand China more, we specially organized them to visit Zhejiang Gongshang University and to participate in the discussion with the graduate students and university students. At this discussion, the representatives from four continents were asked to talk about the different impression or feelings before coming to China and staying China for more than one month. What they felt surprised all those present. As before they came they thought China was a country without any freedom, laying an embargo on free speech about the religion and politics; the police were patrolling on the street everywhere, and the common people were living in the plight of lacking food and clothing. The participants indicated that after returning to their own countries they would tell their colleagues, relatives and friends what was the real China like. Then after listening to the introduction by the University and walking around the new campus, many participants inquired the entrance condition for international students with the strong interest. The quick development of this university left a deep impression to those participants who excitedly indicated several times that this double exchange was surely essential and they enjoyed the great benefit from it.

4. Responding to the call of the Chinese central government "Water conservancy needs going global", we specially conducted several rounds of cooperation discussion with the participants—namely our potential collaborator, such as the participants from Pakistan, India, Macedonia, Turkey, Belarus, Iran and etc. Many participants introduced the 10-year hydropower plan of their own countries to HRC, and they hoped that HRC could supply technological assistance and support for them, including engineering consultancy, equipment provision, and dispatching technical personnel to their countries to implement the SHP technology consultation and training. At present several cooperative agreements have already been reached.

5. In order to provide enriched cultural and recreational activities to international participants, during the training period HRC arranged varied and colorful activities, such as dance party, Kara OK, Ping-Pong match, shopping, local sightseeing, visiting China Silk Museum, calling on HRC staff family and so on. These activities not only make participants obtain the full relaxation in the training period, but also promote their traditional friendship towards Chinese people.

2005 Training Workshop on SHP implemented by HRC was a success. At the closing ceremony, the monitor who was from India put it: "The package of tours including site visits, sightseeing, factories, university, etc. were marvelous. One can not expect more than what you have arranged for us. If you may allow me, in fact we were the luckiest people and the most privileged to be in the city called paradise on earth."

For 2006 HRC is planning to conduct two international training workshops on SHP including one in French for participants from African countries. With its technical service and experience for decades, HRC is committed to participating in more SHP development for African countries and elsewhere in the world. Those interested in our upcoming SHP training workshops may browse HRC's home page and are welcome to contact with us.

(By D.Pan, HRC training coordinator Email: dqpan@hrcshp.org)

FRONT COVER: Nykvarn is a mini-hydropower station located in Linkoping,Sweden, with capacity of 325 kW and a fall height of 2.8m, year production is 1.5GWh, extension torrent of water is 16 m^3/s,midlle torrent of water is 15m^3/s. The station was build in 1942, generator, turbine and gearbox are from that year.Electrical, control and hydraulic equipment are from 1997. Barcleaner are from 2001, and it's without hydraulic fluid, and engines controls with frequency controllers, instead of hydraulic engine.

(By Mikael Halvarsson)