Prospects of Small Hydro Power Plant in Hilly Areas

Awadhesh Kumar[1] Dr. ShriRam[2]
[1]P.G Student [2]Associate Professor
[1,2]Department of Civil Engineering
[1,2]Madan Mohan Malaviya University of Technology Gorakhpur- 273010 (U.P.), India.

Abstract— Hydro power is a renewable energy source, which is economical, environmental friendly and pollution free. Small Hydro Power (SHP) projects have the potential to provide electricity in the hilly areas of the world where the power supply is uneconomical and difficult by the grid system. In most cases small hydro power is "run-of-river" with no dam or water storage. This type of power is very cost-effective and environmental friendly technology of power for the hilly and inaccessible regions of the world. Hydro power is considered as the most successful energy among all renewable energy resources. Maximum small hydro power potential is available in hilly and inaccessible areas of the country, where generation from other sources or supply of power upto long distances is not feasible. All hydropower falls in category of clean power, but small hydro power projects provide more contribution as SHPs needed minimum submergence, minimum rehabilitation and minimum environmental impact. Therefore, in Small Hydro Power, there are great opportunities for harnessing hydro energy in hilly areas of the world. In the year 1897, Small Hydro Power Projects was started in India. In India, the first hydro power station was a small hydro power station of capacity 130 KW commissioned at Sidrapong near Darjeeling in West Bengal in 1897.

Key words: Hydro power, small hydro power project, top ten SHP potential states of India, hydro-electric power plant (A schematic diagram), important components of small hydropower plant, Sheraghat small hydro power project (proposed by the Uttarakhand Government)

I. INTRODUCTION

Hydro power is a source of renewable energy which is non-polluting and environmentally benign. This power is oldest technique for converting the mechanical energy into electrical energy. As we know that the products like petroleum, coal etc. are limited and will not be available in the future time, therefore for decreasing the dependence on these limited resources of power, it is very important to develop the hydro power. This type of power is cost-effective form of electrical energy. This power has additional benefits like flood control, irrigation and tourism etc.

In hilly areas of the world, it is very difficult to provide electricity to the villagers or community by the grid system. The supply of the power in the hilly and inaccessible areas by the grid system is very costly. But, the supply of power in the hilly areas becomes more easy by installing the small hydro power. An extra benefit of this type of power plant is employment to the local people. This power represents use of water resources towards inflation free energy due to absence of fuel cost. Hydro power is very clean source of energy and only uses the water, the water after generating electrical power, is available for other purposes.

II. HYDRO POWER

Hydro power is the power which is derived from energy of falling water at high level. The power station where potential energy of water is converted into electrical energy is known as hydro-electric power station. In hydro power station, a large amount of water must be available at the sufficient head. Therefore, hydro power station is located in hilly areas where dams can be constructed at suitable place to store great quantity of water in reservoir. When water fall, through penstock, on the blades of turbine, potential energy is converted into mechanical energy. Generators are connected with a turbine which converts mechanical energy into electrical energy.

III. SMALL HYDRO POWER PROJECT

The power projects having the capacities up to 25 MW (i.e. 25000 KW) are known as Small Hydro Power (SHP) Projects. The small hydro power project classification is not same all over world. A list of capacity of small hydropower defined in different countries is given in following table:

Country	Capacity of Plant
USA	≤ 5 MW
UK	≤ 5 MW
Sweden	≤ 15 MW
Colombia	≤ 20 MW
Australia	≤ 20 MW
Canada	≤ 20 MW
India	≤ 25 MW
China	≤ 25 MW
Phillipines	≤ 50 MW
New Zealand	≤ 50 MW

IV. TOP TEN SHP POTENTIAL STATES OF INDIA

Name of States	Potential (MW)	Achievements (MW)
Karnataka	4141	1204.752

Himanchal Pradesh	2398	710.11
Uttarakhand	1708	348.86
Jammu & Kashmir	1431	165.18
Arunachal Pradesh	1341	126.13
Chhattisgarh	1107	167.25
Andhra Pradesh	978	253.07
Madhya Pradesh	820	91.06
Maharashtra	794	371.13
Kerala	704	211.17

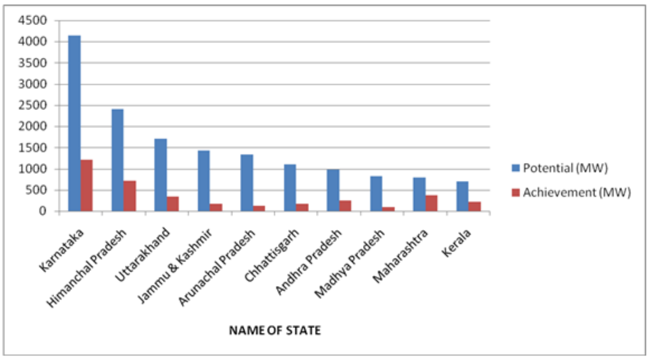

Fig. 1: Comparison of top ten shp potential states of India

From the above graph we get, that these states have the great potential for hydro electric power. The achievement of the hydro power in these states is not great in comparison of the potential of hydro power. Therefore, we have concluded that, there are great amount of hydro power which we have to achieve. In other states also the hydro electric power generation are going to develop. Therefore, we can say that there are more scope in small hydro in hilly areas of the country.

V. HYDRO-ELECTRIC POWER PLANT (A SCHEMATIC DIAGRAM)

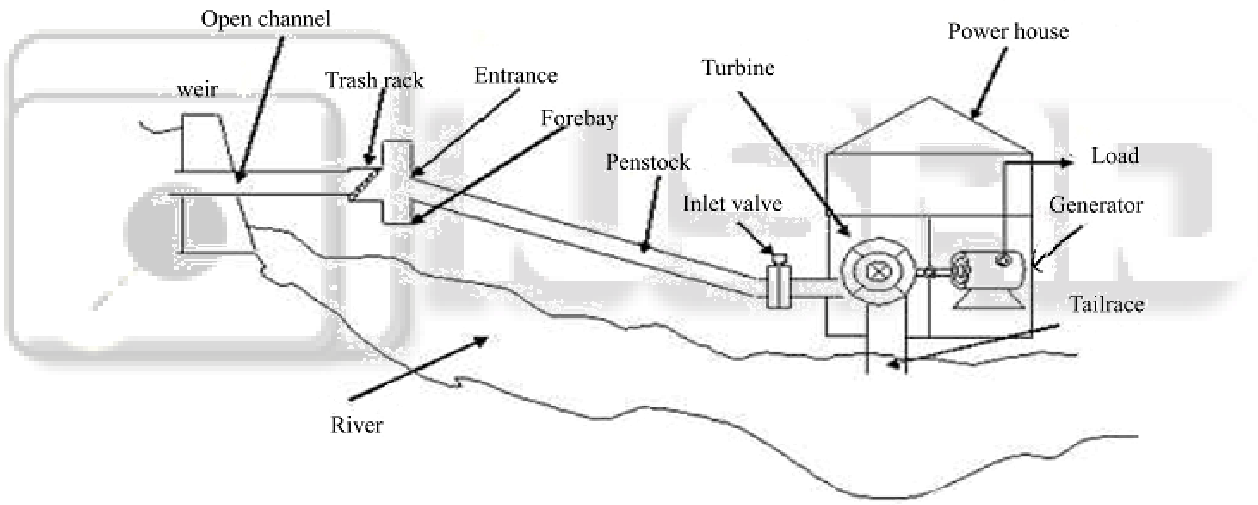

Fig. 2: Hydro-electric power plant

VI. GENERAL EQUATION FOR EVALUATING SMALL HYDRO POWER

The general equation for evaluating small hydro power is as following:

$P = \rho g H Q \eta$ (1.1)

Where, P = Electric power generated in watt

ρ = Density of water (1000 kg/m^3)

g = Acceleration due to gravity (9.81 m/s^2)

H = Net Head in meters.

Q = Discharge or design flow rate in m^3/s

η = Overall efficiency of the turbine, generator and gearbox (may be taken between 0.65 to 0.80)

VII. IMPORTANT COMPONENTS OF SMALL HYDROPOWER PLANT

The important components of small hydro power plants are as following

A. Dam:

A hydraulic structure built across a river to store water on its up-stream side is known as dam.

B. Weir:

The function of a weir is to obstruct water flow and raise the water level significantly and sometimes to allow water storage.

C. Intake:

The function of intake structure is to convey water from forebay to the penstock.

D. Desilting tank:

Out of all the essential civil components, the desilting tank is one of the most vital part of SHP schemes, which rejects the sediment (silt) and foreign particles carried by water through the conductor system and protects the hydro mechanical equipments from the harmful silt carried by the conducting system.

E. Forebay:

It is like a pond at the top of the penstock, which serves as a final settling basin for suspended matters in the water. It also provides submergence for the penstock inlet and accommodates overflow and trash rack arrangements.

F. Headrace:

The water is conveyed from the intake to the forebay by headrace. A typical headrace is made of pipes of good quality materials.

G. Penstock:

Water from the storage reservoir (Forebay) is carried through penstock or canals to the power-house. Penstocks are the pipes of large diameter, usually made of steel in various forms, reinforced concrete or wood stave, which carry water under pressure from the storage reservoir to the turbine.

H. Tailrace:

Tailrace is the channel into which the draft tube discharges.

I. Powerhouse:

The powerhouse provides shelter to the electromechanical equipment (Turbine, Generator, Control and Panels).

J. Substation:

It consists of switchgear and transformers to transform the voltage from the small hydro generator to the higher voltage transmission lines.

K. Spillway:

A spillway is a structure constructed at a dam site, for effectively disposing of the surplus water from upstream to downstream.

L. Turbines:

Turbines are defined as the hydraulic machine which converts hydraulic energy (energy of water) into mechanical energy.

M. Generator:

Generator converts the mechanical energy input from the turbine into electric energy output.

N. Governor:

The governing of a turbine is an operation through which the turbine speed is kept constant under all working conditions. It is completed automatically by means of a Governor, which regulates the rate of flow through the turbines according to the changing load conditions of the turbine.

O. Control System:

These are required to monitor and regulate the power produced from the generators in powerhouse.

P. Transformer:

The transformer inside the powerhouse takes the AC and converts it to higher voltage current.

VIII. SHERAGHAT SMALL HYDRO POWER PROJECT (PROPOSED BY THE UTTARAKHAND GOVERNMENT)

Sheraghat small hydro power project of capacity 10 MW has been proposed to be constructed by the Uttarakhand Government on the Ramganga West River which originates from the Doodhatoli ranges in the district of Pauri Garhwal, Uttarakhand state of India. Sheraghat is situated in the Almora district of the Uttarakhand state. Sheraghat is situated at a distance of 227 KM from the Almora district centre.

The geographical coordinates of proposed site are:

Latitude : $29^0 71^{'}$

Longitude : $79^0 89^{'}$

The Ramganga West River originates from Doodhatoli ranges in the district of Pauri Garhwal, Uttarakhand state of India. The main source of this river is Namik Glacier. The Ramganga river flows in the direction south west from the Kumaun Himalaya. It is a tributary of the river Ganges, originates from the high altitude zone of 800 – 900m. Ramganga flows by the Corbett National Park near Ramnagar of Nainital district from where it descends upon the plains. The city Bariely, Badaun and Moradabad of Uttar Pradesh is established on the bank of this river. The dam Ramganga crosses this river at Kalagarh for the hydro power generation and also for irrigation. It has a drainage basin of 30641 KM^2. This river goes through a number of places. It consolidates many places into one. The important location that this river goes through are Chaukhutia, Masi, Taal, Bhagoti Bhikyasin etc. these places come under Kumaun region.

A. Average Rainfall Of Almora District From 2010 – 201:

In the table below the rainfall of Almora from the year 2010 – 2013 are in millimeter

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	12.0	68.2	0.0	7.3	44.3	72.6	368.7	348.2	480.8	12.3	0.0	13.5
2011	25.6	67.3	14.8	25.1	37.0	190.8	235.5	399.7	164.4	1.6	0.0	2.7
2012	36.5	2.0	25.2	18.4	3.9	18.9	287.6	235.0	162.9	7.0	4.6	24.6

2013	50.6	166.0	13.9	11.9	5.5	310.5	258.1	244.6	55.4	28.2	9.6	9.3

B. *Monthly Average Temperature Of Almora District:*

The monthly average temperature of Almora district in table below is in ^{0}C

Month	Average temperature (^{0}C)
January	9.1
February	11.38
March	14.98
April	17.73
May	22.63
June	23.7
July	24.68
August	24.38
September	23.85
October	19.85
November	15.02
December	10.18

C. *Khosla's Method:*

Khosla (1960) analyzed the rainfall, runoff and temperature data for various catchments in India and USA to arrive at an empirical relationship between runoff and rainfall. The time period is taken as a month. His relationship for monthly runoff is:

$$R_m = P_m - L_m$$

$$L_m = 0.48T_m \text{ for } T_m > 4.5\ ^0C$$

Where: R_m = Monthly runoff in cm and $R_m \geq 0$

P_m = Monthly rainfall in cm

L_m = Monthly losses in cm

T_m = Mean monthly temperature of the catchment in ^{0}C

For $T_m \leq 4.5\ ^0$C, the loss L_m may provisionally be assumed as:

T (^{0}C)	4.5	- 1	- 6.5
L_m (cm)	2.17	1.78	1.52

Annual runoff = εR_m

He supplied provisional values of losses for different temperature. Annual runoff can be estimated as a sum of monthly values. Khosla's formula is indirectly based on the water balance concept and the mean monthly catchment temperature is used to reflect the losses due to evapo-transpiration. The formula has been used on a number of catchment in India and is found to give fairly good results for the annual yield for use in preliminary study.

D. *Runoff Calculation:*

1) *Calculation Of Runoff For The Year 2010:*

Runoff $R_m = P_m - L_m$

Since $L_m = 0.48P_m$

Therefore $R_m = P_m – 0.48\ T_m$

For January
R_m = 1.20 – 0.48 x 9.1 = 0cm
For February
R_m = 6.82 – 0.48 x 11.38 = 1.3576cm
For March
R_m = 0.0 – 0.48 x 14.98 = 0cm
For April
R_m = 0.73 – 0.48 x 17.73 = 0cm
For May
R_m = 4.43 – 0.48 x 22.63 = 0cm
For June
R_m = 7.26 – 0.48 x 23.7 = 0cm
For July
R_m = 36.87 – 0.48 x 24.68 = 25.0236 cm
For August
R_m = 36.82 – 0.48 x 24.38 = 25.1176 cm
For September
R_m = 48.06 – 0.48 x 23.85 =34.612 cm
For October
R_m = 1.23 – 0.48 x 19.85 = 0 cm
For November
R_m = 0.0 – 0.48 x 15.02 = 0 cm
For December
R_m = 1.45 – 0.48 x 10.18 = 0 cm
Annual runoff for the year 2010 = 1.3576 + 25.0236 + 25.1176 + 34.612 = 86.1108 cm

2) *Calculation Of Runoff For The Year 2011:*

For January
R_m = 2.56 – 0.48 x 9.1 = 0 cm
for February
R_m = 6.73 – 0.48 x 11.38 = 1.2676 cm
For March
R_m = 1.48 – 0.48 x 14.98 = 0 cm
For April
R_m = 2.51 – 0.48 x 17.73 = 0 cm
For May
R_m = 3.70 – 0.48 x22.63 = 0 cm
For June
R_m = 19.08 – 0.48 x 23.7 = 7.704 cm
For July
R_m = 23.55 – 0.48 x 24.68 = 11.7036 cm
For August
R_m = 39.97 – 0.48 x 24.38 = 28.2876 cm
For September
R_m = 16.44 – 0.48 x 23.85 = 4.992 cm
For October
R_m = 0.16 – 0.48 x 19.85 = 0 cm
For November

R_m = 0.0 – 0.48 x 15.02 = 0 cm
For Decembe
R_m = 0.270 – 0.48 x 10.18 = 0 cm
Annual runoff for the year 2011 = 1.2676 + 7.704 + 11.7036 + 28.2876 + 4.992 = 53.9548 cm

3) Calculation Of Runoff For The Year 2012:

For January
R_m = 3.65 – 0.48 x 9.1 = 0 cm
For February
R_m = 0.20 – 0.48 x 11.38 = 0 cm
For March
R_m = 2.52 – 0.48 x 14.98 = 0 cm
For April
R_m = 1.84 – 0.48 x 17.73 = 0 cm
For May
R_m = 0.39 – 0.48 x 22.63 = 0 cm
For June
R_m = 1.87 – 0.48 x 23.7 = 0 cm
For July
R_m = 28.76 – 0.48 x 24.68 = 16.9136 cm
For August
R_m = 23.50 – 0.48 x 24.38 = 11.7976 cm
For September
R_m = 16.29 – 0.48 x 23.85 = 4.842 cm
For October
R_m = 0.70 – 0.48 x 19.85 = 0 cm
For November
R_m = 0.46 – 0.48 x 15.02 = 0 cm
For December
R_m = 2.46 – 0.48 x 10.18 = 0 cm
Annual runoff for the year 2012 = 16.9136 + 11.7976 + 4.842 = 33.5532 cm

4) Calculation Of Runoff For The Year 2013:

For January
R_m = 5.06 – 0.48 x 9.1 = 0.692 cm
For February
R_m = 16.60 – 0.48 x 11.38 = 11.1376 cm
For March
R_m = 1.39 – 0.48 x 14.98 = 0 cm
For April
R_m = 1.19 – 0.48 x 17.73 = 0 cm
For May
R_m = 0.55 – 0.48 x 22.63 = 0 cm
For June
R_m = 31.05 – 0.48 x 23.7 = 19.674 cm
For July
R_m = 25.81 – 0.48 x 24.68 = 13.9636 cm
For August
R_m = 24.46 – 0.48 x 24.38 = 12.7576 cm
For September
R_m = 5.54 – 0.48 x 23.85 = 0 cm
For October
R_m = 2.82 – 0.48 x 19.85 = 0 cm
For November
R_m = 0.96 – 0.48 x 15.02 = 0 cm
For December
R_m = 0.93 – 0.48 x 10.18 = 0 cm
Annual runoff for the year 2013 = 0.692 + 11.1376 + 19.674 + 13.9636 + 12.7576 = 58.2248 cm
Average annual runoff from 2010 – 2013

$$= \frac{86.1108 + 53.9548 + 33.5532 + 58.2248}{4}$$

= 57.9609 cm
= 57.9609 x 10^{-2} m

5) Estimation Of The Discharge Of The River:

Discharge (Q) = runoff depth x total catchment area / time
Here catchment area = 30641 KM^2
Discharge Q = (57.9609 x 10^{-2} x 30641 x 10^6) / (365 x 24 x 60 x 60)
= 563.1595 m^3/s

6) Estimation Of The Head Of The Power Plant:

Since power P generated by the hydro power plant is given by

$$P = \rho\, g\, H\, Q\, \eta$$

Where P = Power generated in watt
ρ = Density of water in kg/m^3
g = Acceleration due to gravity
H = Head of the power plant in meter
Q = Discharge in m^3/s
η = Efficiency of turbine

$H = P/(\rho\, g\, Q\, \eta)$
$H = (10 \times 10^6) / (1000 \times 9.81 \times 563.1595 \times 0.60)$
H = 3.0170 m

7) Estimation Of The Height Of Weir:

The relation between head (H) and height of weir is as below:

Head (H) = height of weir – (free board & losses in water conductor system + TWL)
Where TWL = Tail Water Level

The free board can be taken as 0.9 m if discharge (Q) is greater than 9 m^3/s (Ref. K. Subramanya, flow in open channel).

In this, losses in water conductor system can be neglected. And the Tail Water Level (TWL) can be considered as 25% of the total depth of the weir.

Therefore, H = Height of weir – (free board losses + TWL)

Let X = Height of the weir
H = 3.0170 m
TWL = 25% of X = X/4
Free board losses = 0.9 m
Therefore, H = X – [0.9 + (X/4)]
H = X- 0.9 – (X/4)
H = (3X/4) -0.9
3.0170 = (3X/4) – 0.9
(3X/4) = 3.9170
X = 4 x3.9170/4
X = 5.2227 m
The height of weir = 5.2227 m

IX. ADVANTAGES OF SMALL HYDRO POWER

The advantages of small hydro power are following:

- It is a clean process of electrical power generation.
- Low investment is required which can easily be affordable by private entrepreneurs.
- Running, operation and maintenance costs of Small Hydro Power are low.
- Once the dam is constructed, the hydro energy is almost free.
- Since in this plant burning is absent, therefore plant is very clean and neat.
- Generating plants have a long lifetime.

- Hydro power is more reliable than solar, wave and wind power.
- It helps in promoting the local industries in remote areas.
- Electricity can be generated constantly
- Small hydro project helps in generating self employment in remote areas of the states.

X. DISADVANTAGES OF SMALL HYDRO POWER

The disadvantages of Small Hydro Power are as following:

- Small hydro power plant is also a reason of flood for large regions.
- Dam construction cost is very high.
- Power generation is based on the water availability.
- The overflow of water is also affect the plants life.
- Large dam are the reason flood during upstream. It is harmful to human being.
- Selection of place for dam construction is very difficult.
- Environmental problems are also arises due to the construction of the dam.
- The power generation depends on nature and in dry season the generation of power reduces.

XI. CONCLUSIONS

Possibilities of small hydro power in hilly areas are more because, there are water is available at sufficient heads. Due to the hilly areas, the water is available throughout the year. In summer season, the water amount is going to decrease but the generation of power can continuously. In hilly areas, the power plant like thermal, solar etc. are very difficult to establish, because these requires large sites and transportation facility for these sites are also a critical problem. But in small hydro power plant, there is not requirement of large space and does not occur problem of transportation. Due to the availability of hydro power in hilly areas the government is going to establish a large number of small hydro power plant for providing the electricity in inaccessible region of hills. Therefore, in future the possibilities of small hydro power plant will be greater.

XII. REFERENCES

[1] Awadhesh Kumar and Dr. ShriRam, "Prospect of Small Hydro Power in Uttarakhand".
[2] Awadhesh Kumar and Dr. ShriRam, "Development of Small Hydro Power in India"
[3] Annual Report, 2006-2007, Ministry of New and Renewable Energy, India.
[4] Arun Kumar and Praveen Saxena, "Hydropower Development in India".
[5] Alok Kumar Jindal, "Small Hydropower: Technology and Indian perspective".
[6] Central Electricity Authority, Power Scenario at a Glance, New Delhi, April 2010.
[7] Central Electricity Authority, New Delhi (www.cea.nic.in).
[8] Anoop Kumar and S. Khurana, "Small Hydro Power – A review". International Journal of Thermal technologies Vol. 1 No. 1 (December - 2011).
[9] Balour Singh, Davinder Singh (2007), "Small Scale Hydro Power Generation in Punjab, India", International Conference on Small Hydropower – Hydro Sri Lanka.
[10] G.Baidya, "Development of Small Hydro", Himalayan Small Hydropower Summit, October 12-13, 2006, Dehradun.
[11] Dr.P.Saxena (2006), "Overview of Small Hydro Power Development in India" Himalayan Small Hydropower Summit Dehradun.
[12] Dr. Arun Kumar, Dr.M.P.Sharma, Shri Deepak Mathur, Small Hydro Power, Initiative and Private sector participation, 2003, AHEC, IIT Roorkee, India.
[13] D.S.Subrahmanyam(October 2013), "Status of Electric Power generation in India with special emphasis on hydropower expansion".
[14] Guide on how to develop a Small Hydropower plant, Developed by ESHA, 2004.
[15] G.N.Mathur, Dr.A.S.Chawla, Proceedings of 3rd International Course, "Development of Small Hydro", 21-25 April, New Delhi, India, organized by International Association for Small Hydro.
[16] How to develop small hydro sites, Layman's Guide book.
[17] J.O.Jaber(April, 2012), "Prospects and Challenges of Small Hydropower Development in Jorden".
[18] General aspect (2005), Planning for Small Hydro, Himanchal Pradesh, India.
[19] Manoj Kumar Kesharwani 2006, Overview of Small Hydro Power Development in Himalayan Region, Uttarakhand Jal Vidyut Nigam Limited, Himalayan Small Hydro Power Summit, Dehradun.
[20] National Electricity Policy (2005), Ministry of Power, Government of India.
[21] J.Prasad (2007), "Performance evaluation of existing mini hydro power projects of Uttarakhand."
[22] J.K.Kaldellis (2006), "Existing situation of small hydropower plants in Greece"
[23] Merita Borota (2008), "Mini hydro power plants – green power for users."
[24] M.K.Singhal, Arun Kumar (2006), "Cost benchmarking for civil structure of micro/mini hydro electric projects located in Uttaranchal" Himalayan Small Hydro Summit, Dehradun.
[25] Sonali Mitra, "Small Hydro: Too Small for a National Mission?" November 2011.
[26] P.Saxena (October, 2007), "Small Hydro Power Development in India".
[27] Oliver Paish, "Small Hydro Power: Technology and current status", Renewable and Sustainable Energy Reviews 6 (2002) 537-556.
[28] Sarala P.Adhau, "economic analysis and application of micro hydro power plant as the cost is most important issue of development of small hydel schemes."