WATER SUPPLY FROM MAJOR AND SMALL HYDRO-ELECTRIC PROJECTS -SOME PROBLEMS AND SOLUTIONS

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Abstract

Hydro power is a source of clean and renewable energy. In a typical thermal and hydro mix of power supply system, the ideal mix should be 60:40. Due to rapid rise in population and inadequate development of hydro-power, the current mix is about 83:17. It is apparent, therefore, that India must complete the Hydro projects expeditiously. Current status of Hydro power development -both major and small- have been discussed with tables and figures. Apart from power supply, most of the hydro schemes, especially the small hydros- are designed for water supply and irrigation too. Some typical water supply scheme by micro- hydel has been discussed. Some problems of hydro development have been outlined.

1. INTRODUCTION

Hydro-power is a clean and renewable source of energy. Unlike thermal power, it does not pollute air. Properly planned and executed, hydro-power has long life with very little maintenance cost. Unit cost of hydro-electric power is the lowest. The greatest advantage of hydro-power is its flexibility of operation. It is for this reason, hydro-power is generally assigned peak part of load whereas base load is assigned to thermal power in a typical hydro-thermal mix of power supply. Ideal mix of thermal and hydro-power in a power system is about 60:40. The current mix of about 83:17 indicates that India badly needs more of hydro power for economy and stability of power grid supplying power all over the country.

There are countries like Norway where 100% power is supplied by hydro. Canada, USA, Brazil and China have developed 210 GW, 84 GW, 79 GW and 74 GW hydropower respectively, compared to only 38 GW by India as on 30.4.2013.Table-1 gives the hydro-power potential with 60% load factor and hydro-energy potential in some of the countries in the world including India.

Apart from hydro-power, the project proponents offer drinking water, recreation, tourism, infrastructures, education, employment opportunities of poor people living in hilly areas in India. That is why a long gestation period is needed in completion and commissioning of major Hydel projects in India. Execution of major hydro projects is becoming increasingly difficult because of several problems. One of the objectives of this paper is to highlight some of these problems and discuss remedial measures for early execution of hydro- power projects in our country.

Small Hydro projects have a lot of advantages over major projects in this respect, especially in supply of water for domestic use. They need very little storage and can be completed fast with less capital cost. Unlike major projects, small Hydros have, however,the inherent drawback to fight droughts since there is little storage. One of the purpose of this paper is to examine all the aspects as discussed above.

2.0 HYDRO-POWER DEVELOPMENT IN INDIA

The hydro-power potential of India has been estimated as 90,000 MW at 60% load factor equivalent to about 1,50,000 MW installed capacity. Total hydro-power potential of India including pump storage, tidal, river linking, mini and micro hydel schemes is 3,00,000 MW (Mishra, 2013). 60% of India's hydro-power potential lies in Arunachal, Himachal and Uttarakhand states. Table-2 shows the installed capacity (of 25 MW and above) of different river basins in India (Madan,2013).

The Himalayan region is attractive for hydro-power generation because all the rivers in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh descend from around 3,500 m to 500 m in a short distance of 200-km stretch. This water wealth and terrain head are nature's gift and a bounty for the relatively underdeveloped states and for the country as a whole. Our country has planned a large numbers of hydro-power projects, especially in the north east where hydro-power potential is in abundance but development is extremely poor.

Statewise distribution of hydro-power potential of India and the status of development as on 29.2.16 is given in table-3. Out of a total of 2,23,626 MW Installed capacity of India (including thermal, hydro, nuclear and wind), the share of major hydro-power in operation is 37,917 MW i.e. 17 % only against an ideal share of about 40%. Out of 1,45,320 MW of major hydro-potential of India, 94, 900 MW i.e. 65.3% is yet to be developed in the country. Against 197 feasible projects with the potential of 21,212 MW (including major,small and mini/micro) in Ganga and Yamuna basins (table-4), only 38 projects are completed so far with a capacity of about 4,500 MW only.

The present status of hydro development in Alakananda and Bhagirathi basins is that only four major projects - Tehri, Maneri-Bhali-I & II and Vishnuprayag of 3,164 MW capacity have been commissioned. Another five projects are in different stages of implementation. State of Arunachal Pradesh with a major potential of about 50,000 MW has so far developed only 5-6% of hydro-power so far and a large numbers of projects are in the pipeline

Table-1 Hydro power Potential in some of the Countries in the World (Source: Google)

	Canada	USA	Russia	Brazil	Japan	France	Norway	China	India
Hydro Power Potential at 60% Load Factor (10^3 MW)	341	319	160	286	85	78	122	204	90
Hydro Energy (10^6 KW-h)	67	80	44	58	28	78	78	65	23

Table-2 Hydro-Power potential in different River Basins in India(Source:Google)

River Basins	**Installed Capacity(MW)**
Indus Basin	33,832
Ganga Basin	20,711
Central Indian River system	4,152
Western Flowing Rivers of southern India	9,430
Eastern Flowing Rivers of southern India	14,511
Brahmaputra Basin	66,065
Total	1,48,701

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Table-3 State Wise Major Installed Capacity (above 25 MW) in India as on 29.2.16 (Source: www.cea.nic.in)

Region/State	Identified Capacity as per reassessment study	Capacity Under Operation	Capacity Under Construction	Capacity Under Operation + Under Construction	Capacity yet to be developed

	Total (MW)	Above 25 MW	(MW)	%	(MW)	(%)	(MW)	(%)	(MW)	%
NORTHERN										
Jammu & Kashmir	14,146	13,543	31,19.0	23.03	1,180.0	8.71	4,299.0	31.74	9,244.0	68.26
Himachal Pradesh	18,820	18,540	9,308.	50.20	2,216.	11.95	11,524.	62.16	7,016.0	37.84
Punjab	971	971	1,206.	100	206.0	21.22	1,412.	100.00	0.0	0.00
Haryana#	64	64	0.0	0	0.0	0.00	0.0	0.00	0.0	0.00
Rajasthan##	496	483	411.0	85.09	0.0	0.00	411.0	100.00	0.0	0.00
Uttarakhand	18,175	17,998	3,756.	20.87	1,430.	7.95	5,186.	28.82	12,811.	71.18
Uttar Pradesh*	723	664	501.6	75.54	0.0	0.00	501.6	75.54	39.0	5.87
Sub Total (NR)	53,395	52,263	18,302.	35.02	5,032.	9.63	23,334.	44.65	28,928.	55.35
WESTERN										
Madhya Pradesh.	2,243	1,970	2,395.	100	400.0	20.30	2,795.	100.00	0.0	0.00
Chhattisgarh	2,242	2,202	120.0	5.45	0.0	0.00	120.0	5.45	2,082.0	94.55
Gujarat	619	590	550.0	100	0.0	0.00	550.0	100.00	0.0	0.00
Maharashtra	3,769	3,314	2,487.	75.05	0.0	0.00	2,487.	75.05	827.0	24.95
Goa	55	55	0.0	0.00	0.0	0.00	0.0	0.00	55.0	100.00
Sub total (WR)	8,928	8,131	5,552.	68.28	400.0	4.92	5,952.	73.20	2,179.0	26.80
SOUTHERN										
Andhra Pradesh	2,366	2,341	1,746.	74.62	1,010.	43.14	2,756.	117.76	0.0	0.00
Telangana	2,058	2,019	551.0	27.29	240.0	11.89	791.0	39.18	1,228.0	60.82
Karnataka	6,602	6,459	3,585.	55.51	0.0	0.00	3,585.	55.51	2,873.6	44.49
Kerala	3,514	3,378	1,881.	55.70	100.0	2.96	1,981.	58.66	1,396.5	41.34
Tamilnadu	1,918	1,693	1,782.	100	0.0	0.00	1,782.	100.00	0.0	0.00
Sub Total (SR)	16,458	15,890	9,546.	60.08	1,350.	8.50	1,0896.	68.58	4,993.2	31.42
EASTERN										
Jharkhand	753	582	170.0	29.21	0.0	0.00	170.0	29.21	412.0	70.79
Bihar	70	40	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
Odisha	2,999	2,981	2,027.	68.01	0.0	0.00	2,027.	68.01	953.5	31.99
West Bengal	2,841	2,829	312.2	11.04	240.0	8.48	552.2	19.52	2,276.8	80.48
Sikkim	4,286	4,248	765.0	18.01	2,526.	59.46	3,291.	77.47	957.0	22.53
Sub Total (ER)	10,949	10,680	3,274.	30.66	2,766.	25.90	6,040.	56.56	4,639.3	43.44
NORTH EASTERN										
Meghalaya	2,394	2,298	282.0	12.27	40.0	1.74	322.0	14.01	1,976.0	85.99
Tripura	15	0	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
Manipur	1,784	1,761	105.0	5.96	0.0	0.00	105.0	5.96	1,656.0	94.04
Assam	680	650	375.0	57.69	0.0	0.00	375.0	57.69	275.0	42.31
Nagaland	1,574	1,452	75.0	5.17	0.0	0.00	75.0	5.17	1,377.0	94.83
Arunachal	50,328	50,064	405.0	0.81	2,854.	5.70	3,259.	6.51	46,805.	93.49
Mizoram	2,196	2,131	0.0	0.00	60.0	2.82	60.0	2.82	2,071.0	97.18
Sub Total (NER)	58,971	58,356	1,242.	2.13	2,954.	5.06	4,196.	7.19	54,160.	92.81
ALL INDIA	**1,48,701**	**1,45,320**	**37,917.**	**26.09**	**12,502.**	**8.60**	**50,419.**	**34.70**	**94,900.**	**65.30**

TABLE-4: Distribution of Total Hydro-Power Potential (MW) In Ganga &Yamuna Basin

Basin	Major Hydroprojects (above 25 MW)		Small Hydro projects (1-25 MW)		Mini-micro Hydro projects (below 1 MW)		Total Hydro projects	
	No of projects	Capacity	No of Projects	Capacity	No of Projects	Capacity	No of Projects	Capacity
Alaknanda	29	4823	43	375.6	2	0.65	74	5199.25

Bhagirathi	5	675	13	125.5	4	1.4	22	801.9
Ramganga	6	314	12	93.5	2	1	20	408.5
Sharda	26	11920	16	101.95	6	0.33	48	12022.28
Yamuna	17	2670	13	110.3	3	0.55	33	2780.85
TOTAL	83	20402	97	806.85	17	3.93	197	21212.78

3.0 SMALL HYDRO POWER PROJECT(SHP)

Ministry of New and Renewable Energy has been vested with the responsibility of developing Small Hydro Power (SHP) projects up to 25 MW station capacities. The estimated potential for power generation in the country from such plants is about 20,000 MW. Most of the potential is in Himalayan states as river-based projects and in irrigation canals. The SHP programme is now essentially private investment driven. Projects are normally economically viable and private sector is showing lot of interest in investing in SHP projects. The viability of these projects improves with increase in the project capacity. The Ministry's aim is that at least 50% of the hydro potential in the country is harnessed in the next 10 years.

3.1 Hydro Power Project Classification

Basic equation of hydro-power may be expressed as

$$P=9.83\eta\ Q\ H_n$$

Where P is power in KW, η is efficiency of turbine, Q is flow through turbine in cumec and H_n is the net head in meter on the turbine. Net head is obtained by deducting the different losses from gross head i.e. the difference between the intake level and the turbine level in case of impulse type turbine e.g. Pelton wheel In the case of reaction type turbines, (e.g. Francis, Kaplan, bulb head, tubular turbines) gross head is the level difference between water level at intake and tail race level. Type of turbines to be chosen for better efficiency depend on the head available. Where H_n is high, usually impulse type turbine is used. For Medium head , Francis type turbine is used, . For small head, bulb type and tubular type give high efficiency.

Hydro power projects are generally categorized in two segments i.e. small and large hydro. In India, hydro projects up to 25 MW capacities have been categorized as Small Hydro Power (SHP) projects. While Ministry of Power, Government of India is responsible for large hydro projects, the mandate for the subject small hydro power (up to 25 MW) is given to The Ministry of New and Renewable Energy. Small hydro power projects are further classified as

Class	Capacity
Pico Hydro Micro Hydro	Below5KW 5 to 100KW
Mini Hydro	101KWto 2MW
Small Hydro	2 to 25MW

The estimated potential of a SHP project (upto 25 MW station capacity) in India is of about 20,000 MW, of which about 4,341 MW has been exploited. A target of adding about 5,000 MW by 2022 is kept by the Ministry of New & Renewable Energy (MNRE) by installing SHPs. The Indian SHP development programme received a new tempo after the liberalization of economy and invitation to private sector for investment in the power sector. Today, the SHP programme is essentially private investment driven. Electricity generation from SHP is becoming increasingly competitive due to low tariff etc. The challenge is to improve reliability, quality and reduce costs. The focus of the SHP program is to lower the cost of equipment, increase its reliability and set up projects in areas which give the maximum advantage in terms of capacity utilisation. Hydropower represents use of water resources towards inflation-free energy due to absence of fuel cost with mature technology characterized by highest prime moving efficiency and spectacular operational flexibility. Out of the total potential installed capacity of 3,08,834 (as on30.11.2016) in India, Hydropower contributes about 15.37 per cent i.e. 47,457MW (Large Hydro + Small Hydropower). A capacity addition of 88,537 MW is envisaged from different conventional and renewable sources during 2012-2017 (the 12th Plan), which includes 10,897 MW from large hydro projects. In addition to this, a capacity addition of 1300 MW is expected from small hydro upto 25 MW station capacity.

Fig.1 shows a typical micro-hydel installation for water supply in rural/urban areas by diverting water from a canal/storage reservoir. Available terrain head between intake point and power house can be used for generation of hydro-power which can be transferred to power grid for supply of energy for pumping.

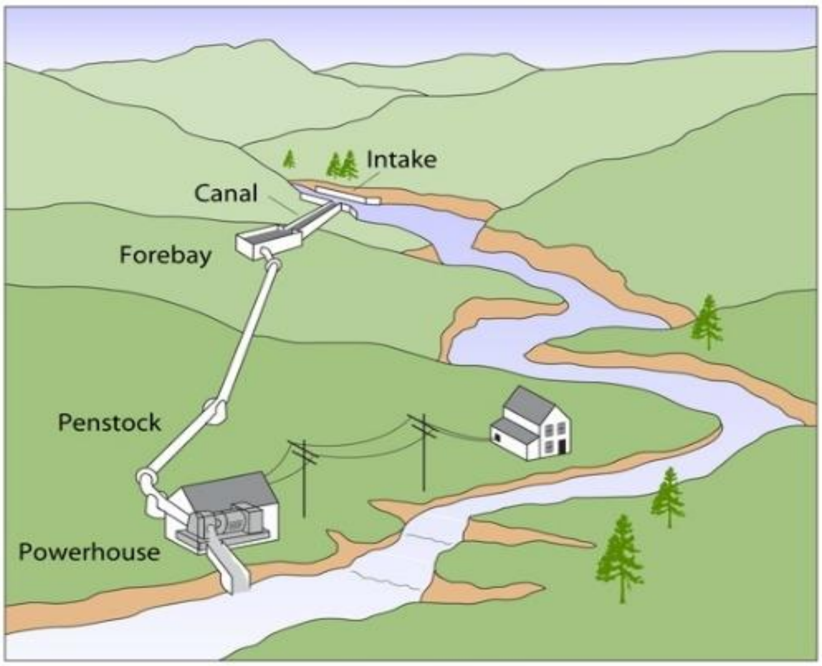

Fig.1 Showing a Typical Small Hydro Project Illustrating Different Parts

3.2 Small Hydro-Power Potential in India (Bhatia et al,2017)

The total hydroelectric power potential in the country is assessed at about 1,50,000 MW equivalent to 84,000 MW at 60 percent load factor. The identified potential of SHP projects is 19,749 MW identified at 6,474 numbers of potential sites, out of which 4324 MW has been harnessed at 1077 sites (as on 31.01.2017). Out of this potential, about 50 percent lies in Himachal Pradesh, Uttarakhand, Jammu &Kashmir and Arunachal Pradesh. In the plain region Maharashtra, Chhattisgarh, Karnataka and Kerala have sizeable potential.State-wise details of the potential are given in Table-5

SHP projects normally do not encounter the problems associated with large hydel projects of deforestation and resettlement. The projects have potential to meet power requirements of remote and isolated areas. These factors make small hydel as one of the most attractive renewable source of grid quality power generation. The MNRE has taken a series of steps to promote development of SHP in a planned manner and improve reliability & quality of the projects. By giving various physical and financial incentives, investments have been attracted in commercial SHP projects apart from subsidizing state governments to set up small hydro projects. MNRE is giving special emphasis to promote use of efficient designs of water mills for mechanical as well as electricity generation and setting up of micro hydel projects for remote village electrification.

3.3 Advantages of Micro Hydroelectric Projects

Micro hydros include projects with a capacity between 10KW and 100KW. Typically these projects can be constructed in the flow of the stream without the need of building a dam. Their negligible environmental impact and their low installation cost offer an interesting opportunity forinvestment either to grid connected systems or to provide off-grid energy to remote areas.

According to the British Hydropower Association (2005), their advantages over other RES are:

§ High efficiency (70 – 90%).

§ A higher capacity factor (typically CF >45%) compared to other RES(PV Systems: CF = 10 – 30% and Wind Turbines: CF = 20 – 30%)

§ Predictability of the energy production.

§ Gradual change of energy production.

§ Hydroelectric generators' quick response to changing conditions.

§ Micro–hydros in streams don't need water storage.

§ Hydro systems have good correlation with demand i.e. the output is maximized during winter.

§ Long-lasting technology. Systems can be engineered to last for more than 50 years, with a low maintenance cost. Moreover, no significant reduction of their energy efficiency occurs with time.

. **Table-5 State Wise Identified Sites and Installed Capacities in MW**

POTENTIAL, INSTALLED & UNDER IMPLEMENTATION (as on 30.11.2016)

State	Potential		Project Installed		Project Under Implementation	
	Nos.	Total Capacity (MW)	Nos.	Capacity (MW)	Nos.	Capacity (MW)
Andhra Pradesh & Telengana	387	978.4	71	232.98	14	40.94
Arunachal Pradesh	677	1341.38	152	104.605	13	10.45
Assam	119	238.69	6	34.11	3	12
Bihar	93	223.05	29	70.7	13	26.9
Chattisgarh	200	1107.15	10	76	4	91.25
Goa	6	6.5	1	0.05	0	0
Gujarat	292	201.97	6	16.6	9	57
Haryana	33	110.05	9	73.5	0	0
Himachal Pradesh	531	2397.91	180	798.81	21	33.5
J&K	245	1430.67	40	158.03	32	35.3
Jharkhand	103	208.95	6	4.05	8	34.85
Karnataka	834	4141.12	166	1220.73	13	70.75
Kerala	245	704.1	31	205.02	12	72.75
Madhya Pradesh	299	820.44	11	86.16	3	4.9
Maharashtra	274	794.33	64	346.175	5	30.35
Manipur	114	109.13	8	5.45	3	2.75
Meghalaya	97	230.05	4	31.03	3	24.2
Mizoram	72	168.9	19	41.47	2	4
Nagaland	99	196.98	12	30.67	2	2.2
Orissa	222	295.47	10	64.625	4	3.6
Punjab	259	441.38	54	170.9	4	4.75
Rajasthan	66	57.17	10	23.85	0	0
Sikkim	88	266.64	17	52.11	1	1.5
Tamil Nadu	197	659.51	21	123.05	0	0
Tripura	13	46.86	3	16.01	0	0
Uttar Pradesh	251	460.75	9	25.1	1	1.5
Uttarakhand	448	1707.87	101	209.32	44	139.54
West Bengal	203	396.11	24	98.5	17	84.25
A&N Islands	7	7.91	1	5.25	0	0

The micro hydel can be installed in existing urban water supply systems. These systems have a constant flow, which results to a predicted, steady energy production. Knowing the water flow during the systems design phase is helpful for a better selection of the various parts. Then, the designed system will function in maximum efficiency. Another advantage is that micro hydros have as a rule a simpler and faster licensing procedure, compared to major hydro. This characteristic boosts the installation procedure and makes the investment more attractive. Micro hydros connected to urban water supply system have an additional advantage. Being inside the urban environment the output might be directly connected to the low–voltage network (in accordance to the local legislation). This option is an important advantage towards the economic viability of the installation, since it substantially reduces the connection cost.

3.4Description of a Typical Water Supply Scheme

Water supply systems usually transfer water from high-elevation mountainous springs to inhabited areas. In order to avoid pipe failure, the pressure inside the network cannot exceed certain limits. Thus pressure breaker tanks (BPT) are traditionally used to relieve the excess pressure. In the revised approach, the installation of hydro–turbines leads to the use of the excess pressure toward energy production. In this way, the potential for energy recovery that typically exists at Break Pressure Tanks (BPTs) is exploited (Kougias et al., 2013)

Other energy recovery possibilities are also possible by varying the turbine positions e.g. the installation on the water storage reservoir. This variation is very similar with the installation in pressure breakers. In that case, water passes through the turbine before being accumulated in the reservoir, which is located in the edge of the inhabited area. Both variations are very flexible, as it is possible at any time to disconnect the turbine from the water supply network, without obstructing the water supply.

Installations of such mini hydropower plants in water supply networks have an increasing number in EU member states. Austria and Italy (Soffia et al., 2010) have extensively followed this practice. Switzerland, with a total number of 90 hydropower plants installed on the municipal water supply network (Byns et al., 2011), is the leading country. Non-EU countries like Turkey (Kucukali 2010) are also exploiting that potential. Planning and management of the proposed approach is important for obtaining maximum environmental, social and economic benefits.

The optimal installation of micro-hydros in a municipal water supply system in northern Greece is presented (Figure 2). The area under study is part of the Aliakmonas river basin; Aliakmonas being the longest river in Greece. The water supply system carries the water from a spring at an elevation of 400m to a small city with a population of 10,000 people. Three Break Pressure Tanks (BPT 1 – 3) enable the control of the pressure which appears due to the elevation differences along the pipeline. The elevation difference between consecutive BPT's is 100m. Installation of micro hydros between BPT-1 and BPT-3 tanks can exploit the available hydraulic height (200m). The distance between BPT-3 and the city's storage tank is 22km. Because of the large distance, the low pipe inclination and the resulting friction losses, the potential for energy production utilizing that hydraulic head is not examined.

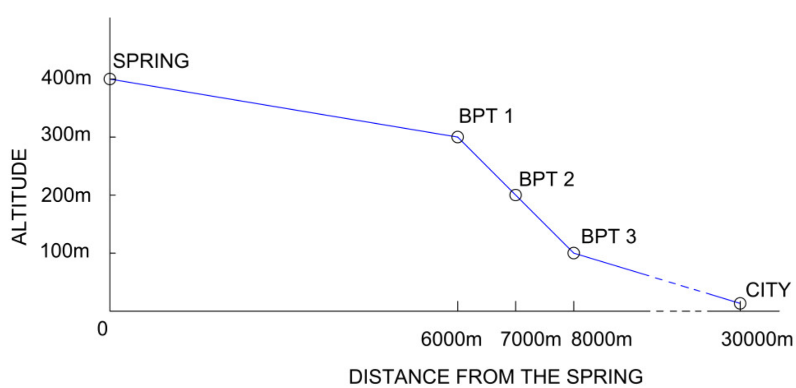

Fig.2 Illustrating Water Supply Line Transfering Water From Spring to a City in Greece. (BPT-Break Pressure Tanks For Safety of pipe and Micro-Hydel generation)

4.0 SOME PROBLEMS & REMEDIAL MEASURES IN MAJOR HYDEL PROJECTS

Execution of major hydro-electric projects in India is being increasingly difficult mainly due to objections raised by several groups of environmental lobby. There is stiff opposition from this group citing several consequences e.g. submergence of land, rehabilitation of affected people, loss of fish and other aquatic life, loss of natural eco-systems, drying of river, silting of reservoirs etc. Some of the problems and remedial measures adopted by developers are discussed in the following paragraphs.

4.1 Submergance of Land and Forest

In major multipurpose projects e.g. Bhakra, Tehri etc. where a reservoir is built with the objective of storing water for irrigation, water supply, hydro-power generation, flood control etc. , a vast area of agricultural and forest land gets submerged. Such hydro-power development is almost impossible now a days because of resistance from people dependent on land and forests.

Run-off the river type developments with limited storage is now a days popular since it creates little storage as the flow is diverted through tunnels to utilize the terrain head for hydro-power generation. Natha - Zhakri and similar other run-off the river type projects with remote installations are being planned to generate hydro-power by diverting dependable flow through long distance tunnels. (Fig.3) Usually, 90% dependable year flow is considered for determining installed capacity by incremental energy method.

4.2 Siltation of Reservoirs

A major problem being faced is the fast depletion of storage capacity due to siltation of reservoirs. Many of the reservoirs built in fifties and sixties are going to be obsolete (Koomullil et.al2015, Mazumder,2016) as their dead storage capacities are full of sediments and their useful life is limited due to fast depletion of their live storage space. In the earlier designs, it was presumed that all the incoming sediments would be deposited only in the designated dead storage space and the useful life of projects will be the design life. However, sediment deposition and distribution of sediments within the reservoir space is dependent on terrain condition, shape of reservoir and other factors (CBIP,1980). In the initial stage of planning, all these factors were not considered.

In the current planning and design of diversion type development, where a barrage is constructed across the river, the height of solid obstruction is kept very small. They are provided with sluice gates and breast walls (Fig4) to create required head for flow diversion in to the head race tunnels. These gates are fully raised during the flood season to wash out the sediments deposited within the reservoir. Since run-off the river schemes are designed for 90% dependable flow only, large volume of water is available for flushing sediments in the monsoon season. It is customary to eliminate sediments of size more than 2mm or so (depending on the head at which turbines operate) by providing desilting chambers within the tunnel. These desilting chambers are periodically flushed out by diverting flow in to the river downstream of barrage.

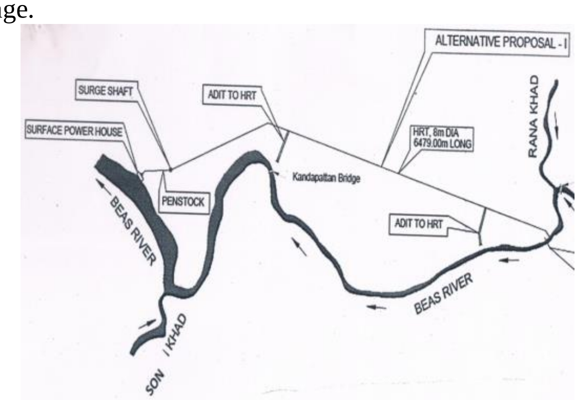

Fig.3 Remote Type Hydro-Electric Installation with Diversion Tunnels in River Beas (Source:HPCCL,2011)

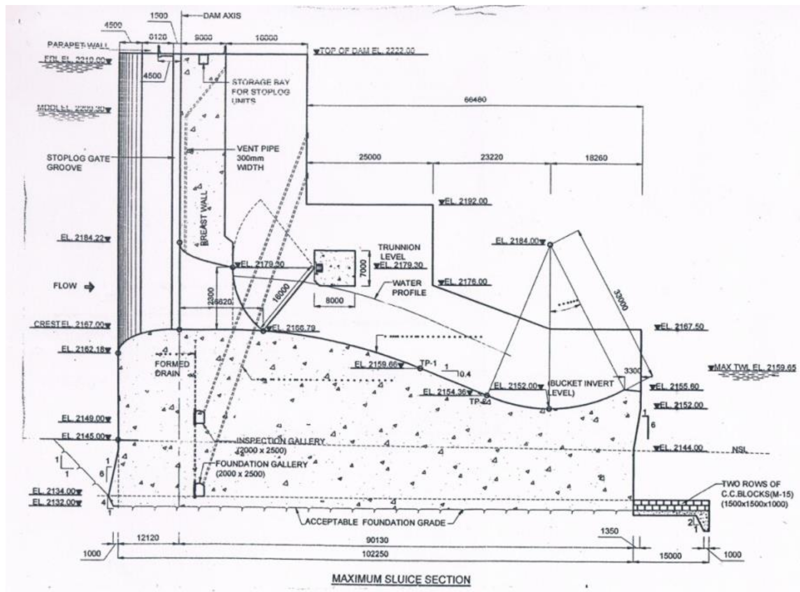

Fig.4 Showing Low height Dam, Breast Wall and Radial Sluice Gates for Flushing (Source:L&T Himachal Hydro-Power Ltd.)

All developers have a tendency to use as much water as possible for generation of power for commercial uses even during the monsoon season. It should be regulated such that water needed for flushing out sediments at intervals are not diverted for power generation. Plant capacities are to be fixed accordingly. Dam toe power house of limited capacity may be permitted.

4.3 Tunneling

In all remote type installations, long tunnels (Fig.3) are to be excavated through the side hills connecting the power house with the power intake. Length of such tunnels is governed by the terrain head to be utilized for hydro-power generation. The terrain head in the tailrace is also used in reaction type turbines e.g. Francis and Kaplan types. Construction of the head race and tail race tunnels by blasting techniques cause not only disturbances to the people living nearby, it may actuate landslides too. The problem is overcome by introducing tunnel boring machines. Tunneling speed is substantially increased by introducing such machines.

Tunnels interfere with ground water flow often resulting in drying up of springs and lowering of ground water table. Local people, depending on ground water, often complain about non-availability of water for drinking and other domestic purposes. Water supply by gravity from ponds at higher elevation through pipe systems is provided at extra cost incurred by the developers. However, maintenance and overhead costs can be borne by people if they are assured of firm piped water supply. Prior to hydro-power development, people used to walk daily down and up the slope which is an arduous task causing lungs and other respiratory deseases.

4.4 Land Slides

Most of the major hydro-power projects are located in mountainous and hilly regions where the terrain is steeply sloping. Often there are landslides due to earthquakes, avalanches and other natural phenomena like high rainfall and run-off. Thorough geological study of such slide prone areas are now-a-days compulsorily carried out for deciding location of barrage, power house, tunnels, residential areas and to avoid geological surprises. Use of software like Geo-slope is a very useful tool for finding stability of hill slopes. Slides can be prevented by rock bolting, geo-textile netting and construction of gabion walls etc.

Mucks generated from tunneling and other construction works are carefully placed at selected sites with terracing and properly designed retaining walls. A minimum of 50m distance should be kept in between the flood line and first retaining wall so that the mucks do not join the river during rainy season.

3.5 Loss of Aquatic Life

All hydro-power projects are responsible for loss in aquatic life like fishes and other aquatic life mainly due to drying of the river in the stretch between barrage and power house. It is for this reason; Govt. of India has enacted to compulsorily ensure a minimum environmental flow usually 20 to 30percent of the lean season flow. Developers have a tendency to use as much dry weather flow as possible for generation purpose. It is very important to monitor that the minimum dry weather flow is admitted to the river from the reservoir either by regulating sluices or by installing dam toe type power house making use of the environmental flow for power generation .

3.6 Loss of Eco-Systems

Environmentalists have serious objection to building hydro-power projects citing loss of eco -system, destruction of animal and plant life, especially those of endangered species. Their views should be respected and all necessary measures are to be adopted to protect eco-systems. Fish passes of improved design should be inbuilt. Minimum dry weather flow ensures aquatic life and natural scenario a river offer to tourists and pilgrims. Elaborate environmental impact study is carried out to delineate endangered species and their protection measures. For every tree cut, new plants are sown; birds and animal sanctuaries are protected; environmental flow is released.

3.7 High Capital Costs

Major hydro-power development needs high capital costs because of long gestation period, acquiring land, rehabilitating affected persons and so on. Developers are required to build roads for communication, buildings for rehabilitation, social improvement by building schools, healthcare facilities, training of local people engaged in the project etc. Although not directly related to projects, such social activities need a lot of money and time. Without these activities, developers face a lot of resistance from local people often misguided by persons opposed to such development and more often by opposition political parties for their vested interest. Project authorities have to convince such people about the utility of the project by convening meetings and publicizing the developmental activities.

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