Future of Hydro-Power Development in Himalayas post Chamoli Flood Disaster

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1. Introduction

The Himalayan region is attractive for hydro-power generation because all the rivers in that, i.e. in Jammu and Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh originate in the Himalayas and descend from around 3,500 m to 500 m in a short stretch of 200 km. This water wealth and terrain head are nature's gift and a bounty for the relatively underdeveloped north and north eastern states and for the country as a whole (Mazumder,2010).

India has planned a large number of hydro-power projects in the north and north-east where hydro-power potential is in abundance (Mazumder, 2017). Abstraction of fresh water by blocking/diverting flow of rivers for power generation is carried out only after a thorough geotechnical and seismic investigations of the terrain. Public requirements, terrestrial needs, forests, animals and aquatic ecosystem are duly considered. Apart from hydro-power, the project proponents offer drinking water, recreation, tourism, infrastructures, communication, education, employment opportunities of people living in the hilly areas of India.

Execution of the hydro projects is becoming increasingly difficult because of high risks, many unforeseen problems and above all environmental considerations. The recent flood disaster in the Chamoli Valley in the state of Uttarakhand resulted in loss of life, damage to hydropower works and other properties has further strengthened the environment lobby opposing hydro-power projects in the Himalayas. After the flood disaster in the Kedarnath Valley in 2013, The Supreme Court of India appointed a high power committee to report on the matter. Going through the report, the Supreme Court observed (SANDRP, 2020)

"We have gone through the Report and, prima facie, we are of the view that the AHEC Report has not made any in-depth study on the cumulative impact of all project components like construction of dam, tunnels, blasting, power-house, Muck disposal, mining, deforestation etc. by the various projects in question and its consequences on Alaknanda as well as Bhagirathi river basins so also on Ganga which is a pristine river".

Thus, the AHEC Report does not serve as a reference for the disaster incidence. One of the objectives of this paper is to highlight some of these issues and the remedial measures for early completion of hydro-power projects in the country.

2. Hydro-Power Potential Of India

The hydro-power potential of India (vis-à-vis other countries) has been estimated as 90,000 MW at 60% load factor (Table-1) 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 about 3,00,000 MW (Mishra, 2013). 60% of India's hydro-power potential lies in Himachal, Uttarakhand and Arunachal states. Table-2 shows the installed capacity of different river basins in India (Madan,2013).

Table-1 Hydro power Potential in some of the Countries in the World

Countries	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-hr)	67	80	44	58	28	78	78	65	23

Out of a total of 2,23,626 MW Installed capacity (including thermal, hydro, nuclear, solar and wind), the current share of hydro-power is 37,917 MW i.e. 17 % only against an ideal share of about 40%. Out of 1,48,701 MW of installed capacity, 94, 900 MW i.e. 65.3% is yet to be developed in the country (Table-3).

Table-2 Hydro-Power potential in different River Basins in India

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**

3.0 State Wise Hydro-Power Development in the Himalayas

State wise distribution of hydro-power capacity in North and North East region of Himalayas is given in table-3

Table-3 Hydropower Not Yet Developed in the North and North East Regions in The Himalayas (as on 2014)

Region/State	Identified Capacity (Northern Region)		Capacity Under Operation		Capacity Under Construction		Capacity in Operation + Construction		Capacity yet to be developed	
	Total (MW)	Above 25 MW(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	9,308.0	50.20	2,216.0	11.95	11,524.0	62.16	7,016.0	37.84
Punjab	971	971	1,206.3	100	206.0	21.22	1,412.3	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	3,756.4	20.87	1,430.0	7.95	5,186.4	28.82	12,811.7	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	18,302.3	35.02	5,032.0	9.63	23,334.3	44.65	28,928.8	55.35
NORTH EAST										
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 Pradesh	50,328	50,064	405.0	0.81	2,854.0	5.70	3,259.0	6.51	46,805.0	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	1,242.0	2.13	2,954.0	5.06	4,196.0	7.19	54,160.0	92.81

4.0. Environmental and social issues and risks in hydro projects

Execution of hydro-electric projects in India is becoming increasingly difficult mainly due to objections raised by several groups of environmental lobby. There is stiff opposition from that 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. There are also risks of failure of hydro power projects due to landslides triggered by earthquake, avalanches, glacial movement/ melting, floods , geological surprises, tunnel construction, etc.

4.1 Run-Off The River/ Remote Type Development

Storage type (Local) development e.g. Bhakra, Tehri, Teesta, etc. is almost impossible to build now a days because of resistance from people dependent on land and forests. Run-off the river type (Remote) 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. A typical diversion type development in river Beas illustrating Barrage, Head Race Tunnel (HRT) and Adits, Penstock, Surge shaft, Power house is shown in Figure-1 (HPPCL, 2011).

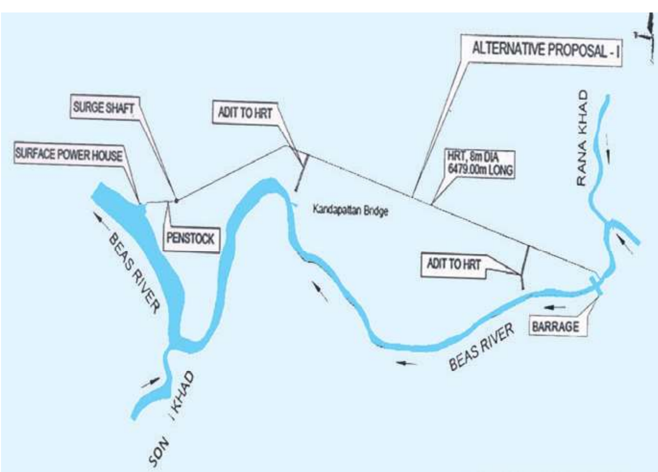

Figure-1 Typical Run-Off the River Hydel Project in Beas River

4.2 Minimum Environmental Flow/ Flushing Sediments

Developers of hydro-power have a tendency to use as much water as possible for generation of power for commercial uses even during the non-monsoon season. However, that should be regulated so that the water needed for periodic flushing out sediments deposited in the pond is not diverted for power generation. Minimum environmental flow should be ensured for aquatic life and river health.

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.al, 2016, Mazumder, 2016) as their dead storage capacities are full of sediments and their useful life is limited resulting in fast depletion of their live storage space. Sediment deposition and distribution of sediments within the reservoir space is dependent on terrain condition, shape of reservoir, inflow of sediments and other factors (CBIP,1980).

4.3 Problems/ Risks in Tunnelling

In all remote type installations, long tunnels (Figure-1) have 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. 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 can be overcome by introducing tunnel boring machines. Tunnelling speed can also be substantially increased by introducing such boring machines. Robotic tunnelling and mucking machines need to be developed to minimise the number of personnel having to work inside and thus the risk to personnel working in the tunnel.

4.3 Problems of Water Supply

Lined tunnels interfere with ground water flow often resulting in drying up of springs and lowering of ground water table. Local people dependent on ground water supply often complain about non-availability of ground water for drinking and other domestic purposes. To overcome this problem, water can be supplied by gravity from ponds at higher elevation albeit at extra cost to the developers. However, maintenance and overhead costs can be borne by local people if they are assured of firm piped water supply. Prior to hydro-power development, local people used to walk daily down and up the slope for fetching stream water from the valley, which is an arduous task often causing lungs and other respiratory diseases.

4.4 Risk of Land Slides/ Muck Disposal

Hydro-power projects are located in mountainous and hilly regions where the terrain is steep. Often there is landslides due to earthquakes, heavy rainfall/ cloudburst with resultant run-off and avalanches. Thorough geological/ hydrological study of such slide prone areas are now-a-days compulsorily carried out for deciding location of barrage, tunnels, surge tanks, power house, residential areas and to avoid geological surprises. Use of software like Geo-slope is a very efficient tool for finding stability of hill slopes. Slides can be prevented/ arrested by rock bolting, geo-textile netting and construction of gabion walls, etc. The design life of these would be around a 100 years hence regular maintenance is also essential.

The muck generated from tunnelling and other construction works is also to be 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 muck does not join the river during rainy season.

4.5 Loss of Aquatic Life

All the hydro-power projects are responsible for loss in aquatic life like fishes and others mainly due to drying of the river in the stretch between the barrage and the power house during lean flow season. It is for this reason that the Government of India has enacted the requirement to compulsorily ensure a minimum environmental flow which is usually 20 to 30 percent of the lean season flow. 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 hydro-power generation.

4.6 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 must be adopted to protect the eco-systems. Fish passes of improved design need to be inbuilt. Minimum dry weather flow ensures aquatic life and natural scenario of a river to attract tourists and pilgrims. The birds and animal sanctuaries are also to be protected. An Environmental Impact study must be carried out. It is important to delineate endangered species and their protection measures. For every tree cut, new plants are to be sown. Several benefits have to be explained/ publicised amongst local people by convening get-togethers. Education of all stakeholders is extremely important for the project to yield its full intended benefits, otherwise developers have to face a lot of resistance from local people often misguided by persons opposed to hydro power, especially those with vested interests.

4.7 High Capital Costs

Hydro-Power development needs high capital costs because of long gestation period in 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 development activities projects would not be supported by the local stakeholders. Project Authorities have to convince the local people about the utility of the project by convening meetings and publicizing the developmental activities.

5.0 Chamoli Valley Flood Disaster

The flash flood disaster in the Chamoli District of Uttarakhand which occurred during February 6th -7th,

Figure-2 Chamoli Flood Disaster – Map showing Rishi Ganga and Dhauli Ganga Rivers (Source: Google Image)

2021 serves as a stark reminder of what can happen if the risks associated with a hydro-power project are not completely enumerated, addressed and mitigation measures put in place for future developments. The debris, rock, and ice flowed downslope in the form of an avalanche, it killed at least 32 people instantly and trapped 150 workers in the underground tunnels, it washed away some villages and wiped out newly constructed barrages and bridges and damaged two power projects in the Tapovan area of the District (Figure-2).

6.0 In Depth Analysis of the Chamoli Flood Disaster

In all likelihood, a steep, hanging portion of the Nanda Devi glacier broke off at Trishuli - what is called a 'rockslope detachment'. This caused nearly 2,00,000 square metres of ice to drop 2 kilometres almost vertically, resulting in snowmelt and landslide, impacting the valley floor and shattering structures instantly. The debris, rock, and ice flowed downslope in the form of an avalanche, identified by the dust trail in the satellite imagery. Additionally, there was likely more ice-cored moraine, or ice covered by sediment, as well as stagnant glacial ice downstream (Figure-3). These large volumes of ice, spanning nearly 3.5 km further downstream melted due to the heat generated by the landslide and avalanche leading to the huge volume of water that flooded down the rivers –Rishiganga and Dhauliganga (Figure-2) which resulted in a sudden rise of the high flood level, very high flow velocity and stream power that caused devastation downstream.

Sometimes glaciers on mountain tops and the sides of mountains build up on account of snow that accumulates from snowfalls. The glacier becomes heavy and unstable and moves when the accumulation goes beyond a certain point. Besides, that there are the deposits of morains and ice often create natural dams (which contain melt water within) forming lakes upstream. Failure of such overladen glaciers or the loose dams because of overflow and sometimes puncture/ breach due to excessive water pressure from water, lead to sudden discharge and consequent flooding downstream.

Figure-3 Left - Snow Fall and Soil Erosion, Right - Avalanche Flow Damaging Barrage
(Source: Google Image)

These phenomena are known as Glacial Lake Outburst Flood (GLOF). Such a GLOF had also occurred in the Kedarnath valley in Uttarakhand in 2013 (Mazumder, 2014) and resulted in the washout of Kedarnath town and instant death of about 3000 people. It also washed away other habitations in its path. Breaching of moraines can be triggered by avalanches, earthquakes or a natural collapse of moraines. The latter was originally suspected to have occurred in Chamoli flood. However, it is not yet clear as to what triggered the original landslide that led to the disaster. Newer satellite imagery, survey data, and further investigations are expected to reveal more information about Chamoli flood disaster that occurred during 6th -7th February 2021.

6. Conclusion/ Recommendation

Electric power is essential for the upliftment of living conditions and hence there is an utter need for hydro-power development in the Himalayan region in India. The untapped hydro-power in the northern and north eastern states are 55.5% and 92.8% respectively. Unlike thermal and nuclear power, hydro power is flexible and highly efficient, especially to meet peak load demand. Ideally, the share of hydro-power in a hydro-thermal mix should be about 40%, whereas the current share is only 17% in India. Although hydro generation needs high initial investment and is time consuming, its maintenance cost is negligible in comparison to thermal power. Besides, there is no consumption of any natural resources and it does not cause any environmental pollution.

Hydro-power development in the Himalayan region through run-off the river type schemes is opposed by the environment lobby in our country on the ground of ecological damage and risks involved in flood disasters due to landslides induced by earthquakes and avalanches in the Himalayan region. Risks are present in all walks of life and so also in engineering projects. The objective should be to assess, analyse and plan credible mitigation strategies to contain or minimise such risks through adequate investigations, data collection and analysis, appropriate planning, design, construction, maintenance and monitoring – physical and remote with predictive analytics. Use of satellite imageries for investigating, monitoring and providing prior signalling of such phenomena should be adopted, considering the great potential of hydro-power and communications need for the development of north and north-east region of India. Recently, the Supreme Court of India approved one and half lane wide road in the Himalayas to connect with Char Dham and the Defence installations in spite of stiff opposition from the environmental lobby. It should be emphasised that natural events like floods, earthquakes, hill slides, glacial breaks and movement, etc. occur even when there is no development like hydro-power, roads, etc. Hence, keeping in mind the fragile nature of the geology of the Himalayan region, it is recommended that institutions exclusively devoted to glacier and mountain research should be established in India, with a view to study, monitor and predict probable occurrence of natural disasters like those that have occurred in the Chamoli valley in 2020 and the Kedarnath valley in 2013 in order to minimise risks and forecast their occurrence to mitigate/ minimise damages from them.

Hydro-power is one way to help achieve the United Nations Sustainable Development Goals viz. SDG Goal 7 which is to "Ensure access to affordable, reliable, sustainable and modern energy for all" and as a consequence SDG Goal 8: "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" and the SDG Goal 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" and others as well.

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