SUSTAINABILITY OF WATER RESOURCES FOR HYDROPOWER DEVELOPMENT

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ABSTRACT

The development of hydropower, a renewable source, is an essential need of any developing country. Presently, in India, the generating installed capacity is only about 25% of hydropower potential i.e. 38,000 MW. The pace of Hydropower development in India has slowed down especially in last few decades. Slow development could be primarily attributed to long gestation period, lack of funds, complex geology of the projects etc. Therefore, to meet country's energy demand at a faster pace and ensure for the lost time, development of Mega hydropower projects are required, which warrants the need of SUSTAINABLE WATER RESOURCES to ensure the continuous availability of water for hydropower generation. The physical geography in Himalayan region provides excellent hydropower potential which was recognised very early in the history of modern hydropower. Nevertheless, there are number of practical obstacles to the realisation of this potential.

Moreover, the vulnerability of the Indian subcontinent to the impact of changing climate is of vital importance because the major impact of climate change in this continent would be on the hydrology, affecting water resources and agricultural economy. Climate change is evident from the observations of increase in global average air and ocean temperatures, precipitation and extreme rainfall, widespread melting of snow and ice, storms/storm surges/coastal flooding and rising global mean sea level.

In the present context, the sustainable water resources are predominantly dependent on the climate conditions which regulate the existence and availability of water on the planet.

Climate change concerns in India include the rising temperatures, the projected variable pattern of precipitations, its intensity and frequency, and the enhanced incidences and intensity of extreme events such as cyclones, flash heavy rains and consequent floods. All these have direct or indirect repercussions on sustainability of water resources. The rivers would certainly be affected by the flood and drought bound to occur due to changed climatic conditions. Therefore, the assessment of climate change on rivers is quite crucial.

The major river systems of the Indian subcontinent, namely Brahmaputra, Ganga and Indus which originate in the Himalayas, are expected to be vulnerable to climate change because of substantial contribution from snow and glaciers into these river systems. It is understood that the global warming and its impact on the hydrological cycle and the nature of hydrological events would pose an additional threat to the Himalayan region.

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The efforts will have to be made towards necessary policy support and development of mechanism for ensuring the sufficient and prolonged availability of water in rivers for fulfilling water requirement of tapped as well as untapped hydropower potential which will not only be achieved by harmonizing diverse institutional structures, distinct sectoral planning & policies etc but also by in communication between the communities of practice at global, regional and national levels.

The paper objective is to identify the impacts on hydropower projects sustainability experiencing significant climate change and variability. Nevertheless to suggest methodologies for assessing the impacts of climate

change on Hydropower projects and suggest suitable interventions for reducing the adverse impacts of climate change on hydropower projects under planning as well as under execution.

1.0 INTRODUCTION

The development of hydropower, a renewable source, is an essential need of any developing country. India, one of the fastest growing economies, is blessed with immense hydro-electric potential and ranks 5th in terms of exploitable hydro-power potential on global scenario. India is endowed with economically exploitable hydro-power potential of about 1,50,000 MW of installed capacity.

Presently, the generating installed capacity is only about 25% of hydropower potential i.e 38,000 MW. The physical geography in Himalayan region provides excellent hydropower potential which was recognised very early in the history of modern hydropower. Nevertheless, there are number of practical obstacles to the realisation of this potential. The region is quite harsh in climate and in some areas construction work is not feasible for a large part of the year. Many prospective sites are in remote locations and their infrastructure development costs associated their development is high which inevitably pushes up the unit cost of installed capacity. This paper briefly deals with these issues.

2.0 EXISTING SCENARIO OF HYDROPOWER IN INDIA

In India about 56 number of pumped storage projects have also been identified with probable installed capacity of 94,000 MW. In addition to this, hydro-potential from small, mini & micro schemes has been estimated as 6,782 MW from 1,512 sites. Thus, in totality India is endowed with hydro-potential of about 2,50,000 MW. However, exploitation of hydro-potential has not been up to the desired level due to various constraints confronting the sector.

As India continues to grow and develop, dependable and reliable energy sources become a pre requisite. In order to achieve the targeted capacity addition, the central government along with various state governments has taken significant initiatives for development of power projects in both public as well as private sectors, with special emphasis on development of hydropower potential of the country to keep a balanced mix of thermal and hydro power generation.

3.0 SUSTAINABLE HYDROPOWER

Hydropower can help mitigate the adverse impact of climate change. As renewable energy, it contributes directly to a low carbon energy future. Hydropower's flexibility supports the deployment of intermittent renewable such as wind or solar power. Multipurpose hydropower can also support adaptation to increasingly difficult hydrology by strengthening a country's ability to regulate and store water and so resist flood and drought shocks. The sustainable Hydropower Development contributes in sustainable Economic, Social and Environmental development.

Fig 1: Sustainable Hydropower: Three drivers

A. Economic

As part of a regional energy strategy and with sound legal and institutional arrangements, hydropower projects can be considered as a tool for economic development, due to its longevity, favourable energy payback periods, their pivotal role in integrated energy systems and their multi-purpose character. The challenge to demonstrate sound and equitable distribution of economic benefits at all stages of scheme development and operation. All significant hydro costs occur at the construction stage. Once constructed, a hydropower project is virtually immune from further inflationary pressures and usually has a very long economic life.

B. Social

With identification and sound management of social issues, hydropower schemes have the capacity to significantly reduce poverty and enhance the quality of life in the communities they serve. The challenge is to ensure that individuals and communities affected by a hydropower development benefit in areas such as improved living conditions, public health facilities, equitable distribution of benefits, social compensation measures. New developments require comprehensive social impact assessment, genuine community engagement, public acceptance and monitoring of outcomes. The interlinkages with environmental and economic aspects of sustainable hydropower must be well understood.

C. Environment

Hydropower schemes do, however, after existing hydrological regime and aquatic ecosystems that are dependent on them and so require sound planning, investigation, siting, design, mitigation, monitoring and adaptive management. Issues that can arise include water quality, sedimentation and abundance and quality of habitat. The challenges are to adequately understand ecosystem components and function minimise creation of new impacts through siting and design. continuous availability of water for hydropower generation may be ensured by sound designs and management.

4.0 INFLUENCE OF CLIMATE CHANGE ON WATER RESOURCES

Water is the primary medium through which climate change influences Earth's ecosystem and thus the livelihood and well-being of societies. Higher temperatures and changes in extreme weather conditions are projected to affect availability and distribution of rainfall, snowmelt, river flows and groundwater, and further deteriorate water quality. The poor, who are the most vulnerable, are likely to be adversely affected.

Water stress is already high, particularly in many developing countries; improved management is critical to ensure sustainable development. Water resources management affects almost all aspects of the economy, in particular health, food production and security; domestic water supply and sanitation; energy and industry; and environmental sustainability. If addressed inadequately, management of water resources will jeopardize progress on poverty reduction targets and sustainable development in all economic, social and environmental dimensions.

Adaptation to climate change is closely linked to water and its role in sustainable development. To recognize this reality and to respond accordingly presents development opportunities. Various necessary adaptation measures that deal with climate variability and build upon existing land and water management practices have the potential to create resilience to climate change and to enhance water security and thus directly contribute to development. Innovative technological practices and implementation of strategies are also needed at the appropriate levels for adaptation as well as for mitigation.

Adaptation to climate change is urgent. Water plays a pivotal role in it, but the political world has yet to recognize this notion. As a consequence, adaptation measures in water management are often underrepresented in national plans or in international investment portfolios.

Therefore, significant investments and policy shifts are needed.

5.0 IMPACT OF CLIMATE CHANGE ON HYDROPOWER SUSTAINABILITY

The global, regional and local environment is changing due to many kind of anthropogenic activities such as green house gas emission, change in land use pattern, deforestation etc. The collective effects of such environmental changes result into climate change. The global atmospheric concentration of $C0_2$ and other green house gases have dramatically increased over the previous century. The increased intensity of climate change in last 50 years is in concurrence with the significant effect on hydrology and water resources of whole India. It will also badly affect the water regime of the Himalayan region.

The discharge in the Himalayan River generally consists of two parts, one which is derived from melting of glaciers and another resulting from the monsoonal rainfall in catchment areas. The discharges derived from the melting of snow make the rivers perennial. The excessive melting of glaciers, due to climate change may increase river flow for next few decades and may subsequently boost power generation in these Himalayan Rivers. On the contrary if we look at the future prospect, the fast melting of glaciers would lead to decrease in snow cover and subsequently decrease in run-off rate of all rivers. The perennial rivers could be changed to seasonal streams which results in water scarcity.

Any change in discharge pattern of river, due to climate change may have profound impacts on huge hydropower potential and also agricultural productivity of this part of world. In future, when the glacial water flow would decline, the energy potential of hydroelectric projects would automatically decrease. This change in water regime has put question mark on energy security of the country. The compilation of data on discharge rate for the previous few years will help us to understand the future situation of water regime in the region and warn us about the future scenario of hydroelectric potential of all the Himalayan Rivers

$$\frac{d(Climate\ Change)}{d(time)} \rightarrow \text{Hydropower sustainability}$$

Further, Climate change is evident from the observations (as shown in Fig 2) of increase in global average air and ocean temperatures, precipitation and extreme rainfall, widespread melting of snow and ice, storms/storm surges/coastal flooding and rising global mean sea level, as recorded in the Fourth Assessment Report of IPCC. In future, Climate change is expected to increase the frequency and intensity of current extreme weather/ hydro-meteorological events, greater monsoon variability and also the emergence of new disaster i.e. sea level rise and new vulnerabilities with differential spatial and socio-economic impacts on communities. This unprecedented increase is expected to have severe impact on the hydrological cycle, water resource (drought, flood, drinking water, forest & ecosystems, sea level / coastal area /losses of coastal wetlands and mangroves), food security, health and other related areas.

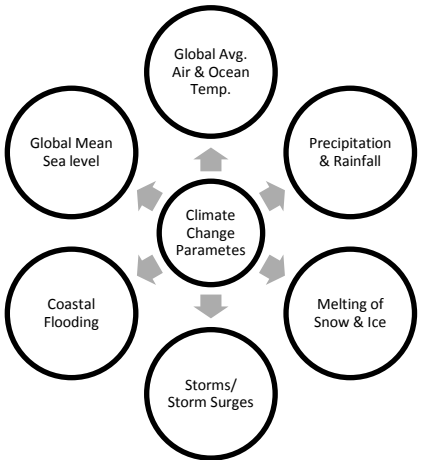

Fig 2: Climate Change Parameters

6.0 PLANNING OF HYDROPOWER

Hydropower is complex integrated power generation system with diverse power generation resources. In the planning of hydro development and deciding on installed capacity etc, these two inter-connections viz. with the water resources developments of the river basin and with the power system are to be kept in view.
In the overall basin context, the impact of operation of upstream projects, constraints imposed by the downstream projects, irrigation diversions downstream, flood moderation etc. are to be considered. Further, with progressive development of consumptive water use and new water resources based development projects in the river basin; water availability would undergo considerable changes over the life of the plant. These are some of the important aspects which have to be considered while planning hydro electric/multipurpose projects.

A key study involved in the planning of a Hydroelectric Project is the assessment of judicious water availability which is based on determination of 50% and 90% water availability years.

As insight of computational details for determination of 90% water availability year would emphasize upon the significance of this parameter.

A. Selection of 90% Dependable Year

Planning of HE Project is carried out based on 90 per cent dependability criteria. For determination of 90% dependable year, the total energy generation in all the years for which hydrological data is available (say N year) is arranged in descending order and the (N+1) x 0.9^{th} year would represent the 90 per cent dependable year.

The 90 per cent dependable year is thus, termed as the year in which the annual generation has the probability of being equal to or exceeds 90 per cent of the time on annual basis during the expected period of operation of the scheme. For example, if inflow data is available for a period of 20 years (N=20),then, 90% Dependable year = (20+1)*0.9= 18.9 = 19^{th} yr

B. Power Potential Studies

Power Potential studies are carried out for assessment of available Power Potential of a river/basin based on a set of inflows and available head conditions under various operating policies. These studies play an important role in the optimisation and design of new hydro facilities. They are used for examination of various configurations and their integration into existing networks. The studies are carried out for optimization of project parameters and for evaluation of Energy and Power benefits.

C. ROR Schemes Without Pondage

In case of ROR schemes without pondage, the flow data is arranged hydrological year wise i.e. June to May etc. and Unrestricted Energy Benefits are worked out for all the years. Based on the above, 90% dependable year is selected. To determine the optimum installed capacity, a number of alternatives of installed capacities are considered and energy generation during the 90% dependable year is computed for each of the alternative installed capacity scenario based on average 10-daily inflows. Installed capacity is selected after carrying out Incremental Analysis for the most attractive alternative. The unit size is selected by considering pattern of generation in various periods, transportation constraints, if any, and system considerations etc.

D. ROR Schemes With Pondage

In case of ROR schemes with pondage, same procedure as for ROR schemes (without pondage) is adopted except that in case of selection of installed capacity, load factor is also considered and studies for cost of alternative Thermal/ Gas and Hydro sometimes carried out in order to work out optimum installed capacity. Hourly operation of the pondage is carried out to work out pondage requirements for peaking. The unit size is selected by considering, transportation constraints, if any, and system considerations etc.

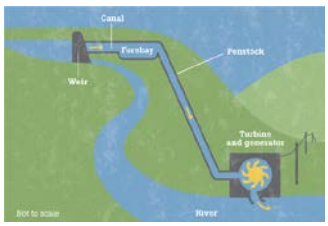

Fig 3: Run Off River Scheme

E. Storage Hydro Schemes (Simulation)

The storage provided at a site can be either for annual operation which means that every year it would be drawn down to its minimum drawdown level or it may be carried over with a view to carry over waters from good hydrological year to the lean flow year that may follow. The purpose of providing storage is to achieve, wherever economically feasible, higher utilization of the inflows approaching very close to the long term average inflows.

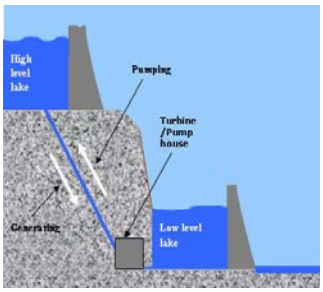

Fig 4: Storage Scheme

The 90% dependable output in case of carried over storages should be higher than the output which would have been possible on the basis of utilization of inflow available on annual basis.

$$Hydropower\ Potenial \propto Water\ Availability$$

$$Water\ Availability \propto f\left(\frac{d\ (Climate\ Change)}{d\ (time)}\right)$$

This proves the fact that hydropower planning of Power potential is dependent on water availability in the basin, irrespective of the type of scheme envisaged in ROR (annual/ carry over reservoir operations). Therefore, the reliability of water availability studies not only for the present scenario but also for the future projection as well i.e. for the entire anticipated design life of the project as a whole is a pre-requisite to be determined.

The assessment of reliability factor associated with water availability is very tedious & vague and is solely dependent on rate of climate change with time. Therefore, ascertaining variation in water availability due to climate change can be attempted qualitatively and the quantification of the same is very complex.

7.0 ADAPTION TO VARIATION IN CLIMATE CHANGE

Adaptation to variation in climate anticipated in future is a wise step for sustaining the developmental growth and minimizing the undesirable consequences on water resources aspects. Certain interventions for reducing and combating with the adverse impacts of climate change on hydropower projects under planning as well as under execution are as follows:

1. Planning and applying new investments (for example, reservoirs, irrigation systems, capacity expansions, levees, water supply, wastewater treatments, and ecosystem restoration).

2. Adjusting operation, monitoring and regulation practices of existing systems to accommodate new uses or conditions (for example, ecology, pollution control, climate change, population growth).

3. Working on maintenance, major rehabilitation and re-engineering of existing systems (for example, dams, barrages, irrigation systems, canals, pumps, rivers, wetlands)

4. Making modifications to processes and demands for existing systems and water users (for example, rainwater harvesting, water conservation, pricing, regulation, legislation, basin planning, funding for ecosystem services, stakeholder participation, consumer education and awareness)

5. Introducing new efficient technologies (for example, desalination, biotechnology, drip irrigation, wastewater reuse, recycling, solar panels)

8.0 CONCLUSION

The growing power demand in India warrants the need of increase in power generation which can be fulfilled by development of reliable energy sources such as Hydropower, Thermal Power and Nuclear Power. Since the Hydropower is a clean Energy and more Eco-friendly, it more reliable than others. Presently, the Existing Scenario of Hydropower in India demands an urgent need of accelerated hydropower development.
In order to meet the continuous power demand, the sustainability of these hydropower projects which are under planning/execution/operation is equally important than the rate of their development. The sustainable hydropower not only ensures the continuous power supply, it also contributes in sustainable development in respect of economic, social and environmental development.

The Climate change is influencing the water resources which are contemplated to have an impact on the sustainability of hydropower projects. It is evident that rate of change of climate is bound to effect the availability of water, sooner or later. This warrants for establishment of a correlation between the variations of availability of water with times to come, which is anticipated to depend upon the rate of climate change. This issue is quite complex and vague for which long term water availability studies coherent with the parameters of climate changes need to be examined prior to deriving any conclusion. But for sure, contemplating this correlation would ensure the rationalization of water availability studies considering the impact of climate change in sustainability of water resources. This would definitely minimize the uncertainties in assessment of hydropower potential and reduce the unforeseen impacts of climate change resulting in combating measures necessitated consequently such as refurbishment of power plants etc. at a later stage, to the reasonable possible extent.

The quantification of climate change is premature at this stage. However, anticipation of probabilistic impact of climate change on water resources would be a wise step in minimizing the adverse impact of climate on hydropower projects.

The necessary steps to minimize climate change impact on hydropower projects would surely benefit the sustainability of hydropower projects.

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