Potential and Challenges in Small Hydro Power Projects in India

Alok Bora, Saurabh Awasthi, and Nafees Ahamed

Abstract The whole world is focusing and striving for clean, green, and renewable energy sources to meet the ever growing energy demand and reduce the environmental impact due to excessive use of fossil fuels. Every country has to contribute in reducing its over-dependence on non-renewable energy and switching to greener options to stop and reverse the damages of ecological imbalance with urgency and sincerity. India being the second most populous country and seventh largest in the world in terms of the land area plays an important role in this. The Indian Himalayan Region (IHR) is a hilly region blessed with many rivers and natural ascent making it ideal for hydropower generation. This paper will discuss small hydropower potential and challenges in India and give probable solutions on ways to overcome these challenges in order to utilize the maximum small hydro potential of the country. Also, it will be discussed how small hydro (including mini, micro and pico) power can play a major role in the generation of clean energy and reduce India's over-dependence on fossil fuels and in turn reducing her carbon footprint. The findings and results will be helpful for other countries as well which have small hydro potential available.

Keywords Small hydropower · Micro hydropower · Pico hydropower · Renewable energy

1 Introduction

With an ever increasing population and never-ending demand for electricity, the journey of India from a developing country to a developed superpower is constantly getting delayed. To accomplish this, one of the most important things—if not the most important—the country will have to achieve is energy sufficiency or in other words state of energy surplus. The reason this is of paramount importance is that energy lies at the very foundation of all other industry or infrastructure projects. Add to this the automobile industry, which is on the very cusp of technological change to go from

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petrol/diesel to electric in the coming years. This in combination with a multitude of other factors is sure to cause an exponential rise in demand and consumption of electrical energy not only in India but all over the world. As a result, to meet this steep surge of energy demand, India will have to up its energy production, relying mainly on renewable energy sources along with a robust and extensive transmission and distribution system if it has to avoid the impending energy crisis and continue on the growth trajectory. Energy consumption is directly proportional to the quality of life of people in any country or specific region and is a universally accepted yardstick to measure the same.

The over-dependence of our country on imported crude oil causes depletion of foreign reserves, which could be used in a better way elsewhere. Pollution due to the burning of fossil fuels and subsequent environmental imbalance is another major concern associated with it. The only solution to this problem lies in developing clean and renewable energy sources within the country which will go a long way in putting India on the fast track of growth and development. For this to actually happen, each state will have to pitch in by identifying and utilizing the renewable energy resources it has been bestowed with, to the maximum. Almost every Indian state has at least one or more combinations of renewable resources available comprising solar, hydro, wind, tidal, etc. Some of these technologies may not be economically viable at the moment but the ones with promise must be pursued aggressively. Although a lot of development has taken place in the country in the last decade in the space of renewable energy, under the Ministry of New and Renewable Energy (MNRE), experts believe that we have barely scratched the surface. A huge amount of untapped renewable energy is waiting to be harnessed. This paper will focus on tapping the small hydropower (SHP) potential in India while also discussing the challenges in its implementation and probable solutions.

There is no doubt that being a renewable energy source hydropower will play a crucial role in contributing to energy generation in the future. International Energy Association (IEA) has stated that hydropower will continue to become a major energy source among the various renewable energy sources in near future [1]. Hydropower is widely considered as a leading renewable energy source and is gaining importance in energy generation all over the world [2–4]. Currently, India ranks 5th in hydropower generation after China, Brazil, United States of America and Canada [5]. Utilizing small hydro potential to the maximum along with medium and large hydro potential is the need of the hour and will go a long way in making India energy surplus.

2 Methodology

The methodology of this paper comprises of acquiring, comparing, and analyzing data from various sources such as scientific literature presented in journals and conferences, various reputed websites including websites of various ministries of Government of India for authentic information on hydropower projects especially small micro and pico hydropower plants. Also, visit to SHP plants to gather first-hand information by Engineers running such plants about the challenges being faced in this sector. An extensive literature review is carried out on the said topic and on the basis of collected data, possible solutions for specific problems in the SHP sector are suggested which can be used as a reference for future SHP works by investors and other interested people in this sector.

3 Classification of Hydro Power Plants

Hydro power plants are classified into large medium and small depending on their capacity. Different countries have different parameters to categorize them. In India their classification is done as follows:

1. Large hydro—>100.00 MW
2. Medium hydro—>25.00 to ≤100.00 MW
3. Small hydro*—>2.00 to ≤25.00 MW
   - Mini hydro—>100.00 kW to ≤2.00 MW
   - Micro hydro—>5.00 to ≤100.00 kW
   - Pico hydro—≤5.00 kW.

*In general any hydropower project less than 25.00 MW is broadly classified as small hydro, therefore, mini, micro and pico are sub-categories of small hydro.

3.1 Formula of Power Generated from Hydro

The formula for hydropower generated is given as

$$P = \eta \rho Q g h \tag{1}$$

where,

P power generated (W)
η dimensionless efficiency of the turbine (approx. 0.9)
ρ density of water (1000 kg/m^3)
Q volumetric flow rate of water (m^3/s)
g acceleration due to gravity (9.8 m/s^2)
h height difference between inlet and outlet (m).

The above equation clearly shows that three out of the five parameters are constants (η, ρ, g), in the given framework, which means that the power developed is directly proportional to ‘Q’ and ‘h’ i.e. volumetric flow rate of water and height difference between inlet and outlet.

3.2 Advantages of SHP

As SHP is a renewable energy source, it has the obvious benefits of being clean, sustainable, and has zero fuel cost compared to non-renewable energy sources like fossil fuels. In addition to these benefits, it has several other advantages also, which makes it among the best and most lucrative in non-renewable category.

The additional advantages of SHP are as follows [6]:

(1) High efficiency (70–90%) which is by far the best among all energy technologies.
(2) High Capacity Factor (typically 40–50%). Capacity factor is defined as ratio of actual energy produced by an energy generating unit in a given time period, to the hypothetical maximum possible (i.e. energy produced from continuous operation at full rated power).
(3) High level of predictability, varying with annual rainfall patterns. Compared to solar, and wind, flow and volume of rivers can be more accurately predicted.
(4) Slow rate of change i.e. the output power varies only gradually from day to day and not from minute to minute as in the case of solar and wind.
(5) It is a long lasting and robust technology. SHP systems can be readily engineered to last 50 years and more.
(6) Can go from stopped condition to full power in just a few minutes.
(7) Installation and commissioning for micro and pico power plants can be done in a few weeks as compared to years in the case of large and medium hydro power plants.
(8) In case of natural calamity like flood etc., the major components can be dissembled and later assembled easily to protect them from getting damaged.
(9) Since SHPs like micro and pico power plants are generally close to load centers, therefore, extensive transmission and distribution network is not necessary in such cases leading to savings in the amount of copper wire, poles, step-up and step-down transformers, and other equipment used. Also, transmission and distribution losses are reduced to a minimum since power does not have to be transmitted over long distances.

4 India's Energy Scenario and SHP Potential

In the past, India has always been an energy deficient country. Although energy generation has always shown year-on-year growth and the percentage of deficiency has decreased over time but the state of energy surplus has eluded the country until now. The bulk of energy generation has been done by fossil fuels especially coal due to its easy availability and low cost. But the last decade has shown tremendous growth in the renewable energy sector and the deficiency has been reduced to an all-time low.

4.1 India's Energy Scenario of Last 12 Years

Before we discuss SHP potential in Indian Himalayan Region (IHR), we have to look at the overall picture of energy generation in the country to understand why it is of upmost importance. Table 1 shows the Indian energy scenario from 2009–10 to 2020–21 [7].

With India being the second-most populous country in the world, its energy requirement is also huge. Figure 1 shows the difference in energy requirement and availability in India from 2009–10 to 2020–21 and Fig. 2 shows the difference in peak demand and peak met in the same period.

Table 1 shows that the energy generation in the country has substantially increased from 2009–10 to 2020–21. The energy deficit has been brought down from double digits to decimal point, which is a commendable achievement. Also, the energy production of the country is on the verge of becoming fully surplus in the coming few years. The total installed capacity of India (as on 28/02/2021) as per CEA is 379,130 MW or 379.13 GW. The figure shows that in the past two Fiscal Years (FY), the energy deficit has been around 0.5% and 0.4% respectively. Although it is a small percentage and work done to bring it down to this level is commendable, we also have to look at the dark side of this data. In a country with a population of almost 1.4 billion, this deficiency means that there are still many villages with a sizable population that does not have access to electricity even at this age. Moreover, there are millions of other people in the country who do not have the luxury of

Table 1 Indian energy scenario from 2009–10 to 2020–21

Year	Energy				Peak			
	Requirement	Availability	Surplus (+)/deficit (−)		Peak demand	Peak met	Surplus (+)/deficit (−)	
	(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)
2009–10	830,594	746,644	−83,950	−10.1	119,166	104,009	−15,157	−12.7
2010–11	861,591	788,355	−73,236	−8.5	122,287	110,256	−12,031	−9.8
2011–12	937,199	857,886	−79,313	−8.5	130,006	116,191	−13,815	−10.6
2012–13	995,557	908,652	−86,905	−8.7	135,453	123,294	−12,159	−9.0
2013–14	1,002,257	959,829	−42,428	−4.2	135,918	129,815	−6103	−4.5
2014–15	1,068,923	1,030,785	−38,138	−3.6	148,166	141,160	−7006	−4.7
2015–16	1,114,408	1,090,850	−23,558	−2.1	153,366	148,463	−4903	−3.2
2016–17	1,142,929	1,135,334	−7595	−0.7	159,542	156,934	−2608	−1.6
2017–18	1,213,326	1,204,697	−8629	−0.7	164,066	160,752	−3314	−2.0
2018–19	1,274,595	1,267,526	−7070	−0.6	177,022	175,528	−1494	−0.8
2019–20	1,291,010	1,284,444	−6566	−0.5	183,804	182,533	−1271	−0.7
2020–21[a]	1,155,130	1,150,891	−4239	−0.4	190,198	189,395	−802	−0.4

[a]Upto February 2021 (Provisional)

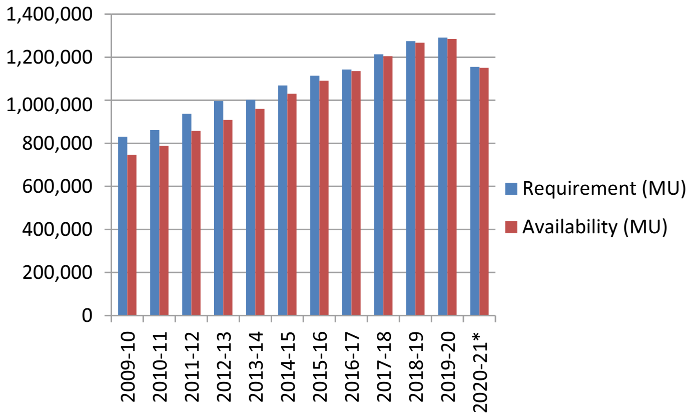

Fig. 1 Shows the difference in energy requirement and availability in India from 2009–10 to 2020–21

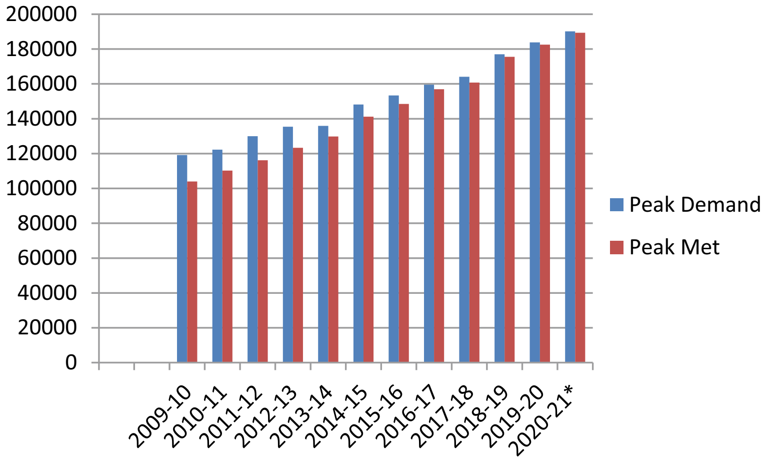

Fig. 2 Shows the difference in peak demand and peak met India from 2009–10 to 2020–21

uninterrupted electricity supply, with constant load-shedding part of their already hard life. This load-shedding sometimes extends up to 12 hours every day at some places. Needless to say, this energy shortage is causing a major hindrance in many an individual's life and also the nation as a whole.

Going by the recent data (early 2021), the energy production currently is fluctuating between being deficit marginally for the most part and going a modest surplus occasionally. This modest energy surplus theory could be attributed to the fact that the country has gone under multiple lockdowns due to the COVID-19 pandemic from March 2020 up to mid-2021, resulting in the closure of various industries, educational institutions, commercial spaces, etc. This closure has caused an obvious reduction in demand and hence the surplus energy state may go back to deficit once the situation normalizes and demand goes back to its peak. Then there is also the perennial problem of uneven energy distribution among cities and villages and various states. For example, the North-Eastern states of India face a higher energy deficit than the national average. This may be due to a multitude of factors but the main reason would surely be transmission and distribution challenges due to the geographic location of these states. In fact, it would not be wrong to say that the bigger problem plaguing the country currently is not energy production but transmission and distribution. The last mile delivery of electricity to every home is quite a challenge in a country as geographically vast and diverse as India. With the current urgency and resolve of the power sector, it is only a matter of time that this will be fully accomplished. However, things need to move at a faster rate by ramping up energy generation especially by renewable methods. This is due to the fact that a delay of each day is causing wastage in the tune of hundreds and thousands of MWs of energy in the form of solar, hydro, wind, etc. The sooner and more of these renewable energies are tapped, the better it will be in the overall scheme of things. It is predicted by experts that by 2030, energy consumption will double and the demand will be tripled.

4.2 India's Current Installed Capacity

The energy generation in the country is done through four major categories comprising of thermal, large hydro, nuclear, and renewable energy sources. Table 2 shows the installed capacity of India as of 28/02/2021 [7].

Table 2 clearly shows that more than 60% of total generation is still dependent on thermal energy sources with coal alone contributing 53% of total generation. Coal although cheap is the biggest environmental polluter and so its usage has to be drastically reduced and substituted with green energy options. This will also be in

Table 2 Installed capacity of India as on 28/02/2021

S. No.	Fuel	MW	% of total
1.	Total thermal	233,171	61.5
a.	Coal	201,085	53.0
b.	Lignite	6620	1.7
c.	Gas	24,957	6.6
d.	Diesel	510	0.1
2.	Hydro (large)	46,209	12.2
3.	Nuclear	6780	1.8
4.	RES (MNRE)[a]	91,154	24.5
	Total	379,130	100

[a]RES include SHP, biomass gasifier, biomass power, urban and industrial waste power, solar and wind energy

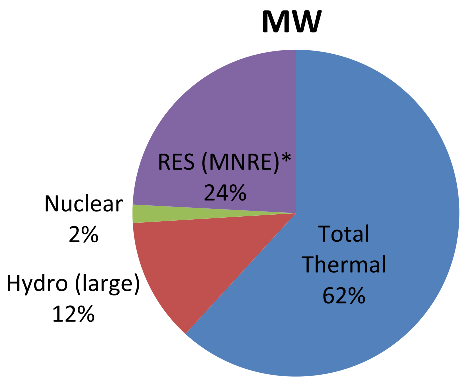

Fig. 3 Shows the share of various fuels in total energy production in India currently (upto February 2021)

line with India's energy goals to boost its renewable power capacity to 175 GW by 2022 (Fig. 3).

4.3 *SHP Potential of India*

India is blessed with many rivers due to which the potential of hydropower is quite substantial in the country. Table 3 shows SHP data of the top five states/UT [8].

The estimated potential of SHP in India is 21,133.65 MW from 7133 sites located in different states of the country [8]. The cumulative capacity target of 5000 MW

Table 3 SHP data of top-five state/UT as per annual report of MNRE, 2020–21

S. No.	State/UT	Total potential		Total projects installed (upto 2020–21)		Projects under implementation		% utilization of energy potential (including projects under implementation)
		Nos	Total capacity	Nos	Total capacity	Nos	Total capacity	
1.	Karnataka	618	3726.49	170	1280.73	3	13.00	34.71
2.	Himachal Pradesh	1049	3460.34	196	911.51	13	151.60	30.72
3.	Arunachal Pradesh	800	2064.92	156	131.11	9	6.05	6.64
4.	Uttarakhand	442	1664.31	102	214.32	14	28.58	14.59
5.	UT of Jammu and Kashmir	103	1311.79	19	146.34	6	31.90	13.58
	Total of all states and UTs	7133	21,133.62	1134	4750.46	96	450.80	24.61

for SHP by 2022 is well within reach as an aggregate capacity of 4750.46 MW has been achieved by 31st December 2020 through 1134 SHP projects. In addition, 96 projects of aggregate capacity of 450.80 MW are at various stages of implementation. The overall target is to achieve grid-connected renewable energy power projects of 175,000 MW or 175 GW by 2022. Four out of the top five in the list comprise of states/Union Territories (UT) in IHR facing more or less common challenges in terms of SHP implementation. The IHR region consists of 12 states/UTs comprising of UT of Jammu and Kashmir and Laddakh and states of Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Tripura, Meghalaya, and Assam. The IHR consists of many rivers and hilly regions which makes it ideal for hydropower production. The actual utilization of SHP in India and particularly IHR is still very low. To substantially increase this utilization percentage, the various stake holders in SHP production will have to work together and remove the bottlenecks which cause hindrance in the implementation of this clean and green technology.

4.4 SHP Potential in Indian Himalayan Region (IHR)

As discussed earlier, the hydropower developed depends mainly on volumetric flow rate of water and height difference between inlet and outlet. IHR is abundantly blessed with both these parameters in abundance. The region has dozens of rivers that are ice-fed and flow all year round (high 'Q'). Also, due to its geographic location, the region boasts of natural hilly terrain and a steep accent (high 'h').

5 Challenges and Risks in SHP

With every energy source, there are certain benefits and risks associated. As of now, there is no perfect or ideal energy source that can be practically harnessed to provide clean, sustainable, and cheap electricity for years and decades to come on a worldwide scale. Although continuous research and development is being done in this sector by the top scientists of the whole world, we are still a few years away, if not decades, to arrive at a possible energy solution. As said earlier, every energy source whether renewable or non-renewable has pros and cons. SHP too has its fair share of downsides. It is important to know the challenges and risks associated with SHP and ways to minimize them before starting any project in this sector.

5.1 Identification of Risks

Any feature, be it benefit or risk can be subdivided into either tangible (quantitative) or intangible (qualitative) features. Tangible features are those which can be expressed in costs and benefits i.e. in monetary terms. Conversely, intangible features are those which cannot be readily valued in money, for example, environmental and socio-economic risks.

The risks in hydropower projects, in general, can be broadly classified into seven categories and then further subdivided into various risk factors. It is important to mention that this is not a complete list but a selection of possible risks. The importance and emphasis of every kind of risk depend on the potential site, target group, technology, and the stage for an implementation of a hydropower plant.

5.2 *Classification of Risks in SHP*

The major classes of risk in small hydropower projects are as follows [9]:

(1) Technical Risk: This risk comprises technical related aspects in the project such as machinery, breakdown, operation and maintenance, as well as the delay from suppliers.

(2) Construction Risk: Construction of a dam is a huge capital investment project. It includes the construction schedule and construction budget risk.

(3) Financial Risk: This risk plays a major role in the small hydropower project. Financial resources, tax rate, and inflation risk come under this risk type. Financial resources can be subdivided into fund blockage and interest rate risk. The exchange rate risk comes into play only when foreign investment is made, which in the case of IHR, is negligible.

(4) Legal Risk: Obtaining the Legal clearances is one of the starting points in SHP projects. It consists of getting clearances as per regulatory. Approvals have to be taken at various levels and from different departments before actual implementation can begin. Public private partnership and norms and rule and regulation changes come under legal risks.

(5) Business Risk: This risk is associated with the situation in which the investor(s) in SHP project run into financial difficulties and not able to generate profit or live up to market expectations. The risk parameters under this category consist of capital cost, electricity price, generation, and modeling techniques.

(6) Environmental Risk: Environmental risks are those factors that may affect the environment or climate of the particular region. These include changes in river flow, precipitation, and flora and fauna.

(7) Socio-Economic Risk: This risk directly or indirectly affects the general population of the region where the SHP project is set up. This risk needs to be minimized to increase the safety and well-being of the local community. The various risks under this category are relocation and rehabilitation, loss of employment, affecting tourist places, noise pollution, changes in water quality, and soil erosion.

5.3 Additional Risks in IHR

In addition to above-mentioned risks, there are several additional risks in SHP which are present in IHR states of India. They are as follows:

(a) Risk of natural hazards:

- Being located in an active seismic zone region, the region is prone to high-intensity earth quakes (especially the state of Uttarakhand). To overcome this problem, a detailed study is required to identify the sites which are low risk and ideal for SHP.
- Floods are also a major concern that can damage not just small and medium but large hydropower plants as well. Floods can cause due to multiple reasons. Major reasons of flood include heavy rainfall, cloud bursts and breaking of glacier or its part.

(b) Damage to the electro-mechanical components of the SHP plant especially the turbine due to silt: Silt is the fine particles of sand that are present in the river. This silt continuously comes in contact with the blades of the turbine and corrodes it gradually over time. This results in a frequent change of turbine and other components which escalates the cost of the plant.
(c) Inaccessibility of project location due to lack of proper motorable roads increases the cost and delays the project substantially. This is because all the heavy equipment has to be transported on foot to the site which is often in a remote location. This may take weeks or even months. This not only delays the project but also puts the equipment at risk during transportation.
(d) Lack of skilled man power that is willing to work in remote locations.
(e) Due to the above reasons and high-risk factors, the interest rate on loans as well as insurance premiums on such projects are on the higher side. This financial roadblock comes across as a major deterrent among the private investors of SHP plants in the IHR states of India.

5.4 Major Natural Disasters in IHR in Recent Times

In the last decade, 2 major disasters have struck IHR region especially the state of Uttarakhand, and 4 more in the bordering countries of Nepal and China which also come in Himalayan region [10]. The chronology of these disasters is as follows:

(1) **Kedarnath disaster, Uttarakhand, India, 2013**

On 16th June, 2013, a flash flood of unseen magnitude hit Kedarnath, Uttarakhand, India. This flash flood occurred due to a cloudburst which caused the collapse of the bank (moraine wall) of the Chorabari glacier lake in Kedarnath [10]. This caused a chain reaction of landslide and huge debris flow causing widespread destruction in Uttarakhand. There was a huge loss of life and property as more than 5000 people lost their lives.

(2) **Chamoli floods, Uttarakhand, India, 2021**

On 7th February 2021, a huge chunk of rock (with snow and ice) detached from Rontigad Mountain and fell into Rontigad River [10–12]. This rock was about 550 m wide and had an estimated volume of 25 million m^3 and fell from an elevation of about 5600 m. This apparently caused huge mass of landslide debris to propagate along the steep slope downstream and pushing Rontigad and Rishiganaga rivers towards Dhauliganga which resulted in hyper-concentration and partly granular flow. The water level at downstream reaches (e.g. at Alakhnanda) exceeded the extreme level which evinces the signature of flash flood. The exact cause for this disaster is still under investigation but based on available information and analysis, the most convincing conclusion is that it was a landslide of a huge rock mass with thick ice/snow and their pulverization leading to debris flow-induced flash flood.

5.5 Effect of Chamoli Disaster on Hydro Power Projects

Due to the Chamoli disaster, Rishiganga hydropower project (13.2 MW, operational) in Rishiganga River near Raini village and Tapovan Vishnugad hydropower project (520 MW, under construction in Dhauliganga River) were severely damaged. Also, some other projects, namely Vishnuprayag HPP (400 MW, under operation) and Vishnugad Pipalkoti HPP (444 MW, under construction) were affected (e.g. closed) by the disaster.

Due to this disaster, the 520 MW Tapovan-Vishnugad hydel project has suffered an estimated loss of ₹1500 crore and it is unlikely that it will meet its scheduled commissioning target in 2023. Also, huge amount of silt is deposited in the project site which will take a considerable amount of time to be desilt by the authorities. The Geological Survey of India has found 13 of 486 glacial lakes in Uttarakhand to be vulnerable through remote sensing and multispectral data [10].

5.6 List of Disasters in Neighboring Countries of Himalayan Region

Apart from the above two major disasters in Uttarakhand, India, a few other major disasters occurred in the neighboring countries of Nepal and China in the last decade [10]. All these disaster hit territories share geographical similarities and therefore offer insights into damage done and precautionary measures that should be taken to minimize the losses.

1. Seti River disaster, Nepal, 2012
2. Jure landslide, Nepal, 2014
3. Glacial Lake Outburst Flood (GLOF), China and Nepal, 2016
4. Landslide (rockfall) hazard in Upper Barun Valley, Nepal, 2017.

The frequent natural disasters in the Himalayan region points to the fact that the region is highly unpredictable and hence vulnerable to such threats. As a result, the hydropower advancements in the region get seriously hampered and investors are apprehensive to put their money on such risky projects.

6 Result and Discussion

6.1 Possible Solutions to the SHP Problems in India

Supplying electricity to remote villages (which are still devoid of electricity) through a state/national grid is economically not viable. This is due to the fact that these remote villages are many and far away from each other and each village has a small population of approximately a few dozens to a few hundred. Due to this, heavy transmission and distribution costs to each of these villages catering to only a few hundred people in every village at most are difficult to justify from financial point of view. The solution to this problem is a decentralized generation and distribution of electricity in such remote places. Electricity can be centrally generated with available resources here and then be distributed with a local grid to every household in the area. In IHR states, SHPs can be the source of generation. This is called as captive power plant i.e. electricity generation facility managed by an industrial or commercial energy user for their energy consumption. The benefit of such captive power plants is that they can operate off-grid but if the need arises due to excess generation, can be connected to the grid to avoid wastage of generated energy. Hence, where ever possible, captive users of SHP should be promoted. Central financial assistance and guidance are available for people who are willing to set up such captive power plants. Such schemes should be advertised on a mass scale to encourage people to become captive users. In this age, when it comes to electricity, people in such remote places should become pro-active and self-reliant and not just fully depend on the government to do the needful. Although this is easier said than done considering that people living in such remote places are generally from economically weaker sections of society, it is also true that with the right guidance and attitude, such villages can be electrified which will cause a paradigm shift in the lives of these people and their coming generations.

The first stage in setting a SHP plant is site selection. Proper planning has to be done for site selection as it is the most crucial part of the whole project as the site cannot be changed after the completion of the project. Since there is a constant threat of natural hazards in the state, proper and in depth risk mapping and hazard susceptibility must be done before starting the project. It is important to do a topographical survey (contour view of the site) which will give us a clear idea of the entire area and therefore enable us to take appropriate decisions on discharge calculation and capacity of the catchment area [13]. In addition to this, the latest technology must be used in forecasting and early warning systems. Emergency action and response plan must be in place in case of any eventuality along with a disaster preparedness and management system. Also, a detailed study must be done on the environmental and socio-economic impact of the SHP plant. Only if the site is favorable in the above-mentioned parameters the project should go ahead. After the site is locked, planning of design, operation, and optimization takes place.

The next stage in setting up an SHP plant is getting the legal compliances. Since many different clearances have to be taken at various levels, this process usually becomes a tiring, time-consuming, and daunting task. To make this process easier and user friendly, the government must introduce a 'single window fast track clearance system' for such SHP projects. Such an initiative will boost investor confidence and help the commissioning of the project much earlier. Also, this would increase the ease of doing business ranking of the state as well.

The next and probably the most important step consist of raising the capital for the project. There exist a few schemes by the government which provide financial assistance to people for setting up such plants. Efforts must be done to popularize such schemes as many interested people are unaware of such schemes by the government. Along with interest free or very low-interest loans, technical end-to-end support must also be provided for the smooth implementation and functioning of the project. For corporate investors who wish to set up SHP plants for commercial purposes, tax rebates in profits can be provided at least in the first few years. This will make SHP a lucrative and potentially profitable business venture for investors.

One of the major costs in hydro projects is the construction of dams or reservoirs which regulate water flow and help in flood control and also provide freshwater for agriculture in addition to generating power. This cost can be avoided for SHPs especially micro and pico by using the run-of-the-river (ROR) hydroelectric generation method where little or no water storage is provided and as such construction of dam or large reservoir is not necessary. However, in some cases, a small storage reservoir can be used which is called a pondage. Another advantage of ROR hydro-electric power is that it eliminates emissions of carbon dioxide and methane gases caused due to decomposition of organic matter in the reservoir of a conventional hydroelectric dam.

The high initial cost of conventional hydro turbines is also the main hindrance in implementing SHP schemes. The cost of these plants can be brought down by using a Pump as Turbine (PAT) [14]. Also, the diversion system has to be planned i.e. whether an open system or closed system will be used to divert water from the source and transport it to the turbine [15]. Also, filters should be used before the inlet valve in case there is a high amount of silt or muck in the flowing water to minimize the damage to the turbine blades.

Another hindrance in SHP is the lack of qualified technicians for its repair and maintenance purposes. Most people who are technically skilled are reluctant to move to remote locations permanently. To solve this problem, the local population needs to be given hands-on skills training in SHP through short-term courses. This will immensely help the local youths to become technically skilled and employable elsewhere too.

Lastly, lack of motorable roads is a major bottleneck in any infrastructure development project due to difficulty in transporting equipment and man power in the proposed site. The same geography which provides the state with natural ascent necessary for SHP also causes a hindrance in the construction of motorable roads due to its difficult and uneven terrain. Although rapid development has been witnessed in road construction in the IHR region in the last decade, the problem still persists in certain remote locations. Completion of the roads will strengthen the last mile connectivity of every village with mainstream cities and towns which will, in turn, usher fast socio-economic growth of people residing in such far-off places.

Due to inherent risks and high costs involved in large and medium hydropower projects [16], it is more logical to develop and utilize small hydropower potential in India. If a large hydropower plant has to be shut down due to technical problems or for repair and maintenance work, then electricity supply is affected for a large number of consumers. However, if micro and pico power plants are installed in large numbers, with each supplying power to a small group of consumers, this problem can be addressed to a large extent. At the simplest and most cost-effective level, micro and pico hydropower plants can generate enough power to charge batteries which can then be used for running electrical appliances of low wattage especially LED bulbs [17], and provide lighting solutions to homes that are not yet electrified.

7 Conclusion

In this study, it was found that IHR states have vast potential for SHP but less than a quarter of that potential has been utilized to date. This shows that there is tremendous scope for growth in this sector in the region. Next, the various problems, risks, challenges, and bottlenecks associated with SHP were identified, both general and region-specific, which are the reason for the low implementation of such SHP projects. After a careful and in-depth assessment of these problems, an attempt has been made to provide possible solutions to every type of risk at every level.

Finding new potential sites in SHP and the risk assessment associated with it is an area of continuous study and research. This part has a lot of future scopes as more research is needed in various technical aspects of SHPs and their working. There are various types of turbines like Kaplan, Francis, and Pelton whose performances can be studied and the one best suited for a particular region can be adopted for that place. There is also vortex turbine that can be tested for SHP in the region. Another upcoming technology is the hydrokinetic turbine which can be set up in canals and controlled rivers.

Although SHP alone will not solve all the energy problems around the world, with the right planning and implementation it can complement the primary grid by serving as secondary power generating unit or decentralized electricity generation grid. This will make the grid more reliable and robust.

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