Feasibility Study of Micro Hydro Power Generation in Raipur-Maldevta Region of Dehradun, Uttarakhand

Somik Juyal [1], Sandeep Negi [2], Amit Verma [2]

[1]*Student, Department of Power System Engineering, VMSB Uttarakhand Technical University, Dehradun, India.*

[2] *Assistant Professor, Department of Power System Engineering, VMSB Uttarakhand Technical University, Dehradun, India.*

Corresponding Author: juyalsomik@gmail.com

Abstract: - Micro-hydro power generation has significant potential to fulfil electricity needs in rural and remote regions, particularly in areas like Uttarakhand, India. This study investigates the untapped micro-hydro potential in Uttarakhand and assesses its viability for sustainable electricity supply. The research analyses water resources, geography, and existing infrastructure to identify suitable micro-hydro power plant locations. Technical, economic, and environmental factors are evaluated to determine the feasibility of utilizing micro-hydropower in the state. The results demonstrate promising opportunities for harnessing clean and reliable micro-hydro-electricity, supporting rural electrification and advancing sustainable energy development in Uttarakhand.

Key Words: — ***Micro-hydro power generation, Load assessment, data acquisition, calculation and result.***

I. Introduction

In modern society, a reliable and uninterrupted supply of electricity has become indispensable for daily activities. From the moment we wake up in the morning to the end of the day, electricity plays a pivotal role in various aspects of our lives. Its significance is so profound that imagining life without electricity is nearly inconceivable. After gaining independence, India relied heavily on thermal power plants to meet its burgeoning electricity requirements. Initially modest, the power demand surged over time due to population growth and technological advancements. To meet these increasing demands and proactively tackle future challenges, innovative solutions were sought to ensure a sustainable and ample electricity supply. The escalating global energy crisis demands urgent attention, prompting the widespread adoption of renewable energy resources worldwide.

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India stands 4th in power generation, but there is a disparity between installed capacity and actual generation. Uttarakhand, blessed with abundant rivers and streams, holds vast untapped hydropower potential, around 3000 MW in small, mini, and micro hydropower segments. Despite this potential, the state spends significantly on power imports. Upgrading approximately 15000 traditional watermill sites to micro and mini hydropower plants, capable of providing 5kW of electricity each, can benefit rural communities and beyond. Community-managed micro hydropower projects, supported by public and private sectors, can sustainably address rural energy demands and stimulate economic growth while preserving biodiversity and human settlements. Recognizing the threat of climate change, the Uttarakhand government sees micro/mini hydropower as a key mitigation initiative. The state's 2015 energy policy focuses on optimizing this untapped power source for community benefit. This research aims to identify effective, overlooked, and cost-efficient methods tailored to the state's terrain and geography. Investigating small hydro cluster development in Uttarakhand can address the region's energy shortage, providing socio-economic insights and techno-economic standpoints. The complexity and adaptability of infrastructure present a logistical rationale, valuable for stakeholders, financial institutions, and government entities across locations and river basins. However, data collection and site access remain major challenges, especially for dispersed sample size evaluation. Despite these obstacles, Uttarakhand's 12 snow-fed river zones offer rich data for input from various stakeholders.

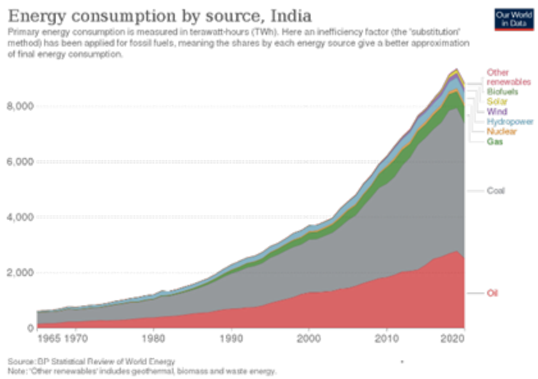

Fig.1. energy consumption of India (source: BP statistical review of Energy)

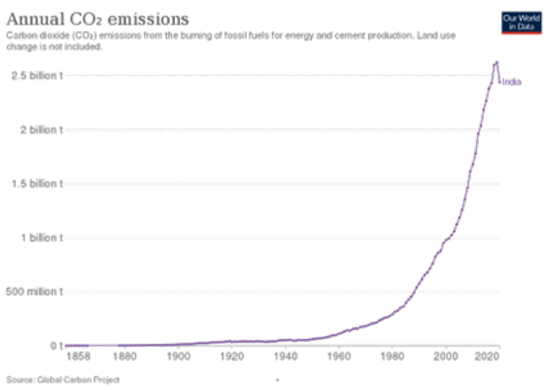

Fig.2. CO_2 emissions.

The Maldevta to Raipur is among the regions with significant potential for hydropower, due to the fact that it is connected by multiple streams originating from the rivers Kali, song and Sahastradhara streams. due to these the channels connected to the rivers observe good flow around the year with an average of 6 cubic feet per second. This region receives 506.77mm of rain annually which adds up to the flow during monsoons making flow reach up to 10 cfs. This makes the region highly suitable for the construction of micro hydropower plants. This power plant is the best alternative for electrification costing relatively low to other means. This study aims to provide data on:

- Potential of water resources for micro hydropower plants.
- Ability of the plant to sustain and drive the load.

This study showcases the potential of generation by MHP in the selected region with the goal of obtaining great potential capable of providing an economic and eco-friendly power alternative to the region.

II. DATA ACQUISITION

2.1 Study Site

This research was carried out in the Raipur-Maldevta region of Dehradun, Uttarakhand. The region is positioned at the footsteps of the Tehri hills which provides the area with an elevation of 705 metres and 654 metres for Raipur. With a channel flowing through the region sourcing water from multiple rivers, the stream is called 'Kalanga'. The area is depicted in Fig. 3 with the marked area representing the region.

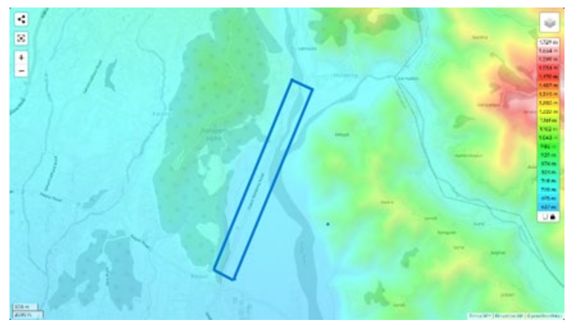

Fig.3. map depicting the study site.

In the study area, location surveys were conducted to gather data.

2.2 Hydrological Data

In this study, the data regarding the flow of the stream was calculated by conducting multiple surveys and site visits. The channel of the stream was observed, and multiple points were selected throughout the channel. Individually the flow was calculated for every point and the average of all was taken as the final value.

Since the channel of the stream is not the same throughout, flow variations were observed. The calculated flow for the stream was 6 cubic feet per second which crosses the minimum requirement of 1cfs. Fig.4 shows the water channel about which the data was collected. The volumetric flow rate method was employed to calculate the flow rate(ft^3/sec). the formula is:

$Q= A*V$

Where;

Q= volumetric flow rate (ft^3/sec)

A= cross-sectional area(ft^2)

V= velocity of the stream(ft/sec)

Fig.4 on-site water channel.

2.3 Elevation and Head

Elevation refers to the height above the reference level, usually the sea level whereas the head is the vertical distance or elevation difference in a fluid system, crucial for hydropower generation, pump design, pressure analysis, and water resource management. It represents potential energy and aids in efficient fluid conveyance and environmental impact assessment.

In this study, the elevation and head calculations were done by using the data from the topographic maps of the region. The elevation from the beginning of the study site i.e., Maldevta was observed to be 708 metres and for Raipur, it came out to be 654 metres.

Since the region is a footstep to the mountains of the Tehri and Mussoorie the region was elevated and hence the flow channels for rivers were formed. The head so obtained is 54 metres which provides enough energy for water to maintain a stable flow. fig,5 depicts the elevation of the site

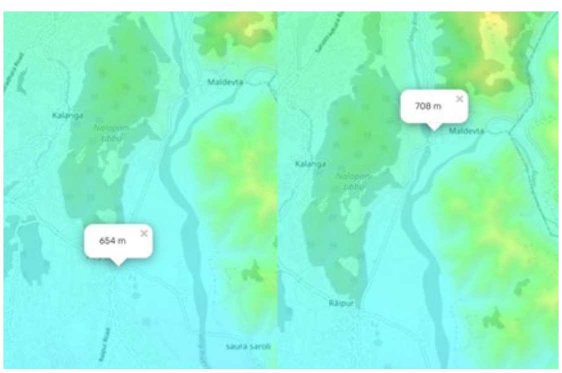

Fig.5 Elevation of the study site.

2.4 Load Assessment

Load assessment involves evaluating power demand, forecasting future consumption, and optimizing energy usage for stable and efficient electrical systems. It aids utilities and industries in planning, reducing peak loads, and ensuring reliable power supply. Load assessment is crucial for stable, efficient, and reliable electrical systems, enabling effective energy management and cost optimization. It aids utilities and industries in meeting power demands, reducing peak loads, and ensuring uninterrupted power supply.

For the estimation of load, multiple electricity bills from different regions falling into the same load category were studied to get an average on the load requirement of the region.

On taking the average the load requirement was calculated to be 2kWh per day. It is important to note here that the area taken into consideration was a rural/outskirts area and not an urban area hence the load consumption was this much. It was observed while observing the load consumption of multiple areas that the load in the rural areas can be as low as 1kWh per month and can go up to as high as 600kWh per month.

Therefore, an estimation was done while taking into consideration the basic load needs i.e., bulbs, fan chargers, etc to solidify the load requirement.

The purpose of a micro hydro power plant is to provide an economic alternative for supplying the basic needed power requirement. Hence a micro hydro power plant is a suitable alternative for fulfilling the power needs of off-grid areas. The load requirement of the off-grid areas varies as compared to urban and more connected areas.

The site selected had a cluster of 20 houses making up a community which makes the total load requirement reach a value of 40kWh during peak times.

2.5 Turbine Selection

Turbine selection is crucial for a hydropower project due to its impact on efficiency, resource utilization, economic viability, environmental impact, maintenance, safety, scalability, and access to the latest technology. Proper selection ensures optimal performance and long-term success. Collaborate with experts for informed decisions.

Kaplan and Francis turbines would be the possible options for this type of operation. However, each turbine has its own operational characteristics and has to be selected wisely for the optimisation of the system.

For the specific set of data and the operation according to the research, the best-suited choice would be to use the Kaplan turbine as it can operate in the medium head with a variety of flows. Kaplan turbines are known for their efficiency in medium to low-head applications and can accommodate a wide range of flow rates.

Using a Kaplan turbine for the micro hydro application offers advantages due to its high flow rate handling, adjustable blades, low head suitability, compact design, and cost-effectiveness, making it a favourable choice for fluctuating flow rates and varying water conditions. Fig. 6 showcases a model of the Kaplan turbine.

Fig.7 Kaplan turbine (source: Wikipedia)

The efficiency of a Kaplan turbine can vary depending on its design, operating conditions, and specific application. Generally, Kaplan turbines are known for their relatively high efficiency across a wide range of flow rates and heads. The Kaplan turbine efficiencies are typically high and often exceed 90%, especially in medium to high-head applications where they excel. In medium-head applications, Kaplan turbines are known to achieve high efficiencies, typically over 90%. This makes them well-suited for power generation in locations where the head is moderate, usually falling within the range of tens to a few hundred meters.

The head available for the selected site is 54 metres which falls under the category of medium-head, the Kaplan turbine is best suited for this operation.

2.6 Generator Selection

Synchronous generators are widely used in micro hydro plants due to their constant frequency, grid synchronization capability, and overall efficiency. They are well-suited for grid-connected systems and can provide stable and reliable power output. Synchronous generators are a popular choice for micro hydro plants supplying electricity to local grids or communities. Of all the available generator options synchronous generators are widely preferred over other generator types. In context with the site and the specific data, To meet the 40 kW load demand, the generator should have a rating equivalent to or slightly higher than the apparent power required.

2.5.1 Generator Sizing.

Generator sizing for a hydropower system involves determining the appropriate generator capacity to meet the electrical demand of the load and account for the efficiency and power factor of the system. The formula for generator sizing/apparent power is;

Apparent power (kVA) = Total Power Demand (kW) / Power Factor.

Generator Size (kVA) represents the apparent power rating of the generator, measured in kilovolt-amperes. It indicates the generator's capacity to handle the load demand efficiently. Total Power Demand (kW) refers to the overall electrical load demand, measured in kilowatts, which in this case is approximately 40 kW. Power Factor is the efficiency ratio of real power (kW) to apparent power (kVA) in an AC electrical system, denoting how effectively electrical power is converted into useful work. In this scenario, it is assumed to be 0.8. Therefore;

KVA = 40kW/0.8

Apparent power (KVA) = 50 kVA.

Opting for a slightly higher-rated generator ensures reliability, accounts for load variations, starting surges, and future expansions, prolongs the generator's lifespan, and prevents overloading, offering a safety margin. In this case, a generator with a rating of 60KVA or above should be chosen to support the load. This approach allows the generator to effectively meet the load requirements of 40 kW while also accommodating any fluctuations in power output and providing room for potential future load expansions or changes.

2.7 Generation Potential

The power potential of a hydropower system refers to the maximum amount of electrical power that can be generated by harnessing the available water resources, specifically the flow rate (Q) and head (H) of the water source. It represents the upper limit of electricity that can be generated by harnessing a particular energy source or technology under ideal conditions. The power potential is usually measured in kilowatts (kW) or megawatts (MW). Generation potential is an essential concept in energy planning and resource assessment, as it helps determine the feasibility and capacity of renewable energy projects. It allows stakeholders to assess the total energy potential of a particular resource and estimate its contribution to meeting energy demands and reducing carbon emissions.

Generation potential is crucial for energy planning, resource assessment, and sustainable development. It guides policymaking, promotes renewable energy, reduces emissions, enhances energy security, and fosters economic growth while preserving the environment.

In this study, the site surveys have given a set of data which can be compiled and used in calculations for

finding out the power it can deliver. The electrical output of the MHP scheme can be shown as follows;

P_e= G*n_t*n_g*H

$_{net}$*Q [Kw].

Where:

P_e= power generated

G= gravity = 9.81m/s

$n_{t=}$ turbine efficiency = 0.9(Kaplan turbine)

n_g= generator efficiency = 0.9(synchronous generator)

H = head (m) = 54 metres

Q = water discharge(m^3/sec) = 0.17m^3/sec.

According to the formula,

P_e = 73 kW (taken round off)

The provided data demonstrates that the power generation potential of this region, through a micro-hydro power plant, is sufficient to generate up to 64 kW of power. This indicates that the setup can adequately meet the electricity demand of the community cluster in the area which has a load requirement of 40kW(50KVA). Hence, the rating of the generator in terms of apparent power (KVA) is;

Ratings (KVA)= KW/power factor

= 91 KVA

Therefore, for a micro-hydro site with a potential power output of 64 kW and a load of 40 kW, it is advisable to select a generator with a capacity of at least 73 kW(91KVA). By choosing a generator that matches the site's potential power output, you ensure that it can handle the maximum power production without overloading. Considering the generator sizing, the generator required would be capable to support future load expansion and surges due to the potential of the plant.

2.8 Environmental Risk

The presence of a dedicated channel through which the water flows naturally facilitates the establishment of a micro hydro power plant with minimal threats to the surrounding nature. The implementation of such a power plant takes advantage of an existing waterway without significantly altering the natural flow patterns, thus mitigating any adverse impacts on the local ecosystem. The channel acts as a conduit for the water to pass through the power generation process, ensuring that the overall hydrological balance remains largely undisturbed. As a result, the risk of habitat disruption, biodiversity loss, or negative effects on aquatic life is markedly reduced. This environmentally conscious approach allows for the harnessing of renewable energy while preserving the integrity and ecological value of the surrounding natural environment, exemplifying a harmonious synergy between sustainable energy development and nature conservation.

III. RESULT

The comprehensive potential generation assessment of the micro hydro power plant and the in-depth feasibility studies conducted have resulted in highly successful outcomes. The findings reveal a substantial power generation potential at the site, accompanied by strong technical and economic viability. The successful assessment not only confirms the feasibility of the project but also lays the groundwork for the development of a sustainable and reliable micro hydro power plant. This project holds immense promise, poised to make a significant contribution to fulfilling the region's growing energy demands while advancing environmental sustainability objectives.

IV. CONCLUSION

Micro hydropower plants represent a compelling renewable energy solution that can significantly impact regions blessed with abundant water resources. As we seek to transition away from fossil fuels and combat the challenges of climate change, the establishment of well-designed micro hydro projects becomes paramount. The mentioned region's unique characteristics, including its favourable location, substantial water availability, and suitable elevation and flow conditions, create an ideal environment for the implementation of such plants.

The benefits of micro hydropower plants extend beyond environmental considerations. These projects hold the potential to deliver stable and consistent electrical power to communities, reducing their dependence on costly and unreliable non-renewable energy sources. By harnessing the natural flow of water, these plants generate clean and eco-friendly electricity, contributing to reduced carbon emissions and a greener footprint for the region.

Moreover, the rural and off-grid areas in the region stand to gain immensely from such initiatives. Access to electricity is a fundamental catalyst for social and economic development, providing opportunities for education, healthcare, and entrepreneurship. Micro hydropower plants offer a decentralized and sustainable approach to electrification, bringing power to remote communities and positively impacting their quality of life.

The economic benefits of micro hydropower are equally compelling. Once established, these plants have low operational costs and minimal environmental impacts, making them economically viable in the long run. Moreover, the revenue generated from surplus electricity can be reinvested into local development projects, further boosting the region's growth and prosperity.

However, the successful implementation of micro hydropower projects requires meticulous planning, community engagement, and regulatory support. A thorough assessment of the local environment, water resources, and potential impacts on ecosystems is vital to ensure the projects are designed and executed sustainably. Community involvement fosters ownership and understanding, building a supportive foundation for the projects' success.

In conclusion, micro hydropower plants offer a promising pathway towards a more sustainable, inclusive, and resilient energy future for the mentioned region. By tapping into the power of water, these projects present a win-win solution that meets the region's energy needs, stimulates economic growth, and nurtures environmental stewardship. Embracing this renewable energy opportunity is a critical step towards a greener and more self-sufficient society, driven by the vision of a prosperous and harmonious coexistence with nature.

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