Remote village electrification by small hydropower project in Assam

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Abstract

A study for development of strategic pathways for a cluster of three villages in Karbi Anglong district of Assam, viz, Bichithur, Borgang and Ahomborigang, based on decentralized energy plans to meet energy needs for subsistence is being taken up with the broad objective to develop an integrated energy plan which is flexible, adaptable, ecologically sound and an optimal mix of new and renewable energy sources. A survey of energy consumption and demand pattern has been carried out in the cluster. The questionnaires have been filled by old persons and head of the family of the surveyed households. A full menu of options is being considered hybridizing all possible renewable energy technologies, biomass, small hydro and solar energy, in an integrated system as convergence of RE technologies is considered as one of the facets of energy service provision affecting the livelihood opportunities of the poor and understood in the terms of how the poor value and use it.This paper thus presents the identification, design and development of a 1.8 MW small hydro power generation unit which will be an integral part of the blue print of a decentralized integrated energy plan for the area which may be taken as an example for rural upliftment in other remote villages of Assam.

***Keywords*:**Environment, Electricity, Forebay tank, Headrace channel, Spillway

1. Introduction

The State of Assam is a land of villages and the rural poor's problems such as unemployment and poverty need to be addressed. There should be integrated development that includes not only agriculture but also decentralized rural industries to provide work to agricultural laborers, small and marginal farmers and others. Sustainable Rural Energy Planning and Rural Electrification is one of the key sectors of energy usage having wide spread social impact. The application of renewable sources of energy would be of greatest benefit in the short and long term on account of its social dimension. Electricity is most important for sustainable development. It does not automatically provide development paths but it does represent a tool capable of economic, educational, health and other sectoral advancements that are ingredients for controlling one's developmental destiny [1]. In rural areas, electricity is a vehicle for information flow, enabling a community to take part in affairs beyond its village confines, and making national,political and social cohesion a meaningful concept. So unless concrete steps are taken to energize all the villages, there will always be a barrier to socio-economic development of the rural areas and hence of the State.

Planned interventions to reduce energy scarcity in rural areas can take various forms such as (a) energy conservation through use of energy efficient stoves for cooking, compact fluorescent bulbs in place of incandescent bulbs, (b) supply expansions through energy plantations and (c) renewable energysources such as micro/mini/small hydro power plants, wind, solar and biomass based systems depending on availability of such resources in the region[2]. Ecologically sound development of the region is possible when energy needs are integrated with the environmental concerns at the local and global levels. There is thus a need to develop area specific integrated energy plan taking into account spatial and seasonal variation in resource availability, energy demand etc.

2. Materials and methods

2.1 Study area

***2.1.1.Location*:**The project area selected is a cluster of three villages, viz., Bichithur, Borgang and Ahomborigang, of Karbi Anglong District of Assam situated about 80 km away from Guwahati. It lies within Longitude 92 degree 22' E and Latitude 26 degree 03' N. This area falls within two hill districts Karbi- Anglong and North Cachar Hills, of Assam. It is 25 km from Jagiroad and its nearest railway station is the Guwahati Railway Station.

***2.1.2. Climate*:**The Temperature of the area is 35 to 38ºCin summer and 6 to 8ºC in winter. The Relative Humidity varies from 60 to 80%. Period of Rainfall in the area is from June to October and the average annual rainfall is 3745.65 mm.

***2.1.3.Population*:**Borgang is the largest village with approximately 138 households. Bichithur has 13 house-holds and Ahomborigang has about 49 house-holds. Thus the study area has 200 households, with a population of about 1000 people.

***2.1.4.Social structure of the people*:**The whole area is inhabited by tribal population with fragile socio-economic condition belonging to the lower income group. Majority of the men-folk work as laborers in the nearby tea and rubber plantations and a few works in shops in nearby Jagiroad town. There is only one primary school in the village and for high schools and colleges students have to go to neighboring towns. The medical unit is just a primary health centre, for hospitals the inhabitants have to travel to Guwahati. The houses in the cluster are a mixture of pacca and kaccha houses. The literacy rate is very low and most are school drop-outs. The tribal people of the area have ordered and organized life-style. All the matters relating to the entire community is decided at the village level itself by a village head-man called Gaonbura appointed by the authority of Karbi-Anglong Autonomous Council. The people practice both conservative methods of cultivation as well as jhum cultivation. The population growth rate is at 22.62%.The sex ratio is 927 females to 1000 males. The fertile land of the area is suitable for rice, tea, rubber, bamboo, orange, pineapple, etc. Almost all the people of the area rear cattle and produce sufficient quantity of milk which is supplied to nearby Jagiroad. The area is rich in handicrafts and it is the main occupation of the women folk, who weave their own dresses, table cloths, bed covers etc. Bamboo and cane is available in large scale in this area and artisans make baskets, bamboo furniture and beautiful hats of different shapes and sizes.

2.2. Objective

To look into the problem of energy supply in the study area, identify the renewable resources available locally, calculate the energy demand and solve the problem by designing an integrated energy plan to generate energy for the area by small hydro power, biomass etc (this paper discusses only the small hydro-power project).

***2.2.1. Problem of energy supply in the study area*:**One of the major constraints in improving the living conditions of the people of the area is the non- availability of electricity and a sustainable energy system for meeting their daily needs. Kerosene is used by many households for lighting purpose, but the majority cannot afford to use it due to their low purchasing power. There is no supply of LPG for cooking, and people use dung cakes, fire wood etc, in a non- scientific manner, causing damage both to themselves as well as to the environment. This has affected the health of the women-folk as they have to go to long distances to collect fire-wood from the jungles. Basically this lack of electricity has an adverse effect on their life style and has also affected their agricultural activity and their industrial production. This in turn has adversely affected their economy. The evening hours are mostly dark causing a sense of insecurity and people fear to venture out. Much productive hours in the evening are thus lost leading to alcohol abuse by the villagers.

Availability of electricity at community level, modern technical know-how on cultivation and irrigation, availability of better seeds etc will help the people of the area to implement strategies for agriculture development at a faster rate. Thus, steps must be taken to generate electricity in the area by renewable energy sources and develop an area specific integrated energy plan to solve their cooking needs, agricultural as well as industrial needs, by taking into account spatial variation and seasonal variation in resource availability, energy demand etc.
Salient features of the village are shown in table 1

Table 1:Salient features of the village cluster, obtained from survey

Particulars	Data
Total number of houses	200 households
population and occupation	1000 (approximately).80%.based on agriculture
Education- Literacy rate	30%
Total land area	15 sq km
Net crop sown	Rice, tea, rubber, bamboo.
Forest area / wasteland	6 sq km/ 15 hectares
Animal population	Total 692 (including pigs)
Energy resources	Kerosene, cow dung,firewood
Rural industries	Cottage industry, weaving, cane and bamboo artifacts.
Drinking water resources	River Sunani

2.2.2. Identification of renewable energy resources in the area*:**This area had been identified by Assam Energy Development Agency (AEDA), as potential area for generation of energy by renewable energy sources. Thrust has been given on biomass, solar and hydro power generation.***

Assessment of potential renewable energy resources in the area has been done and has been identified as follows-

***2.2.3. Biomass resources*:**The village is surrounded by forest on all sides.8 sq km of forest land and 15 hectares of waste land is available in the locality. Semi evergreen forests are widely prevalent in the area and have commercially important species like Badam, Amori, Cham, Tita Sepa, Nahar, Shimul, Ghogra, Ejhar, Odal, Sopa, Bonsum, Bogipoma, etc. Bamboos are available in abundance in the area. The forests of the locality are extensive and rich in minor forest products like Cane, Patidoi, Dhuna, Agar, Dalchini, and a variety of medicinal plants. There is a continuous supply of biomass within the area for a Biomass gasification plant to generate electricity. An energy plantation in 7Hectares of land is proposed for the future. Most of the villagers rear cattle for milk and cow dung from domestic cattle is used as a cooking fuel. The villagers may be encouraged to use improved chulhas/cooking stoves. The dung available in the village is sufficient to meet the energy needs of the villagers for cooking purpose by construction of community Biogas plants.

2.2.4. Solar energy:The data collected from the area shows daily solar radiation of 5.44 kWh/m^2/day and it is estimated that there is enough potential for solar energy utilization in the vicinity. Solar grid may be envisaged for solar home lighting and solar street lighting within the village area.

2.2.5. Small hydropower resources:Bichithur village is located close to the bank of Sunani River. It has a small hydro site located in the catchment of Sunani stream. The project has been envisaged to utilize the hydro power potential of the river by using perennial discharge available in Sunani stream.

***2.2.6. Load estimation by survey*:**Door to door survey done in the village, covered the willingness of the villagers to adopt the renewable energy system. The required load estimation for the village is shown in Table 2.

Table 2: Proposed Daily Use Requirement of electricity for the village

Use	Daily Use requirement of	
	Power (kW)	Energy (kWh)
Domestic Use	27.0	189.0
Public Lighting	0.360	1.440
Drinking Water Pumping	0.373	1.119
Sub Total (Item 1 to 3)	27.733	191.559
Future Expansion @15%	4.05	28.35
PH Consumption, Losses etc. @ 15%	5.102	33.4
Total	36.885	253.309
Capacity Taken as	50.00	254.00

***2.2.7. Integrated energy planning proposed for the village*:**It is proposed to generate 50Kw electrical energy from Biomass gasification process which will be used within the village. The cooking problem of the village is sought to be solved by Community Biogas plant from 5 digesters each of capacity 20 m3/ day. The street lighting problem of the entire village will be solved with the help of 20 numbers of Solar Streetlight systems. Another 1.8 MW small hydro power generation unit described in this paper will be an integral part of the blue print of the decentralized integrated energy plan for the area. The extra electricity generated will be sold off to the nearest grid and the fund will be utilized for the upliftment of the area.

2.3. Bichitur small hydro site

2.3.1. River location and proximity to the project area:This area lies near a small river Sunani which originated from Hadbu region and flows in the N-NE direction for about 35 km to join the Borapani River. The elevation ranges from 700 m in the upper reaches to 400 m near the project site. The stream has a total length of about 20.0 km up to the project site. During the course of its long journey, it is joined by several small nallahs.Most of the rainfall within the catchment area occurs during the monsoon seasons of June to October. There is also some amount of rainfall during the pre monsoon and post monsoon periods. The average annual rainfall in the catchment area is about 2300mm.The stream basin receives varying amounts of rainfall ranging from a minimum of 1000mm in the upper reaches to about 4000 mm in the foothills annually and the average rainfall is quite high.Comparatively, less variation in flow and a high discharge and bed slope makes the stream suitable for setting up a small –hydropower project. The catchment is covered by dense forests,which give the advantage of maximum run-off of the rain water into the stream and minimum inflow of silt. The project site is 3 kilometers away from Bichithur –Borgang village.

***2.3.2. Seismicity and geology*:**The project lies in Zone V as per the seismic zoning map of India incorporated in Indian Standard Criteria for Earth-quake Design Structures (IS: 1893-1970). As there is hardly any pondage, it would not lead to any reservoir inducedseismicity.The project site is located on coarse porphyritic granite which is one of the predominated litho units ofthe area.

***2.3.3.The catchment area and head of the project*:**The catchment area at the project site is 76.225 sq km.The gross head was calculated as 30 m (by survey of elevation difference). Net head is taken at least 3% less than gross head.So net head H = 28.2 m. Full water level at Forebay is kept at EL394.489m and Tail water level at EL 367.489m.

***2.3.4 Methodology used for design anddevelopment of the small hydro site for power generation*:**Small hydro projects can generally be categorized as either "run-of-river developments" or "water storage (reservoir) developments "Run-of-river" refers to a mode of operation in which the hydro plant uses only the water that is available in the natural flow of the river and implies that there is no water storage and that power fluctuates with the stream flow. The Bichithur-Borgang small hydropower project is Run-of-river type. Hydrologic Parameters, Water availability studies, Design flood calculations have been done as cited in [3] .

3. Results and discussion

3.1. Hydrologic parameters, water availability studies and calculation of 10 daily discharge series

Within the project area there is no hydro-meteorological network. The flow data available at nearby Baithalangsu gauge site(catchment area, 1633 sq km) for the period 1968- 1975, and at nearby Amtreng Gauge site(catchment area,1268 sqkm)for the period 1984- 1992 is being used to finalize the flow series at Bichithur project on proportionate catchment area basis. The 10 daily series for Bichithur hydro scheme for 17 years has been derived by using Borapani flow series based on catchment area proportionate basis and have been used for planning purpose. As it is not based on site specific data, this flow series needs to be reviewed when site specific observed flow series of longer periods would become available.

3.2. Design flood/ Maximum flood discharge calculations

A significant component of hydrological studies is the estimation of Design Flood or Maximum Flood Discharge. Any obstruction by a dam across a river must have adequate arrangements to pass a pre-determined flood over the structure. The selection of such flood is very important from cost point of view as well as safety of the structure and risk of population involved in the upstream and downstream of the structure. A Design Flood Discharge must therefore be adopted after much consideration of both economic and hydrological factors and safety to life and

properties. The Design Flood for small hydro projects must be for a 50 year or 100 year return period flood. A 100 year return period flood has been worked out for this present scheme.
The following empirical relationship was used to estimate Design Flood;

$Q_{max}=CxA^{3/4}$ … (1)

Where; Q_{max} = Maximum flood discharge in 100 years, m^3/sec.
A = Catchment area.
C = a constant which differs for hill and plain areas.
After calculation, Q_{max} was found to be 200 m^3/sec.

3.3. Calculation of yield in million units (MU) and capacity fixation:

To calculate the yield in million units, the following empirical formula has been used;

$P=9.81xQxHx\eta$ ….. (2)

Where P= Total power in MW.
η = efficiency of turbine/ generator, usually taken as 90%.
Q = discharge in m^3/sec (from 10 daily series)
H = Net head in m.
The power P is calculated to generate a series for Unrestricted Power.
Next the Power Restricted to 0 .15 MW, 0.5 MW, 0 .75 MW, 1.00 MW. 1.25 MW, 1.80MW, 2.00 MW, and 2.25 MW were calculated for each year to generate a series. The total annual generation in one year is obtained by simple addition for each year.
The Probability of Exceedence has been calculated from the Unrestricted Power series.
We than choose the value of Power Restricted which matches with the Unrestricted Power at 90%, 50% and 75% dependable year.
For Bichithur Borgang it was found that,
Based on 90% dependable year, Power must be restricted to 1.25 MW
Based on 50% dependable year, Power must be restricted to 1.80 MW
Based on 75% dependable year, Power must be restricted to 1.80 MW
1.80MW installed capacity, with a probability of getting water for 75% of time, shall be a prudent option with a good balance between plant capacity utilization and optimum use of river discharge. The annual energy generation in a 75% dependable year would be 4.24 MU.
Thus the Capacity of the plant is fixed at 1.80 MW.

***3.3.1. Unit size*:**After much consideration 3 units of capacity 0.60MW each, has been chosen.

3.3.2. Calculation of design discharge Qd:Design Discharge has been calculated using the formula;

$P=9.81xQ_dxHx\eta$….. (3)

Where Q_d = design discharge.
H = Net head in m.
η = efficiency of turbine/ generator usually taken as 90% i.e. 0.90
P= Total power in MW (1.8 MW)

3.4. Conceptual layout and planning

***3.4.1. Diversion weir*:**Trench type diversion structure has been proposed to divert the water from the stream to the Power Channel. A Trapezoidal trench weir (1.5 m bottom width and 2.25 m top width and depth varies from 0.25m to 0.85 m) is provided in the full stream. The top level of the trench is kept at EL 396.00m. The slope in the trench is kept as 1 in 20 to ensure non -deposition of silt in the trench. A horizontal trash rack at 25mm clear spacing in full width of the trench is provided so that entry of stones, boulders etc. into the weir is checked.

***3.4.2. Feeder and head race channel*:**The water fed from the Diversion Weir is led to Desilting Tank through a rectangular feeder channel of length 17.0m. The water from Desilting Tank to Forebay Tank is carried by 281.0 m long Head race channel. The design discharge for Feeder Channel is taken as 8.64 cum/ sec and for Head Race Channel it is taken as 7.92 cum/sec. The design discharge for head race channel is 10% higher than that of Power draft to keep provision for seepage losses and evaporation. For the feeder channel it is kept 20% higher than the Head Race Channel, to meet the flushing requirement of the Desilting Tank. Trapezoidal section with concrete lining is proposed for Head Race Channel with a bed slope of 1 in 300 to suit the natural contour of the ground.

***3.4.3. Desilting tank*:**As the stream carries appreciable quantities of coarse silt during rainy season, a Desilting Tank is designed for a design discharge of 7.92 cum/sec. The flow velocity is reduced to 0.22 m/ sec by increasing the width of the channel. The size of the tank is fixed, based on the time taken by the particles to settle down.

***3.4.4. Forebay tank*:**The Forebay would be located on a relatively flat area followed by the Penstock provided along moderately sloping hillside leading to the Power House. The Forebay is provided to ensure supply of intermediate water demands on starting the generation units.
Storage time is kept 2 minutes as per guidelines by the Central Electricity Authority – 1982. Accordingly the size of the tank is kept as 3.3 m x 10 m x 30 m keeping storage allowance for free board, silt storage and allowance required for passing discharge over Spillway.

***3.4.5. Spillway*:**In order to allow the water to escape from the Forebay Tank in case of emergency shut down of the machine, a Spillway is provided on one side of the Forebay Tank.
The spillway is designed for 7.2 cum/ sec of discharge. The depth water required to pass the discharge is determined as 0.60 m. So the crest of the Spillway is kept 0.60 m below the full supply level .Total crest width is provided at 10m.

***3.4.6. Penstock design*:**Water from Forebay is taken to the Power House to run hydraulic turbine through pressured penstock pipe. The Diameter and thickness of Penstocks are designed from the considerations of Head of water and Amount of Water (Discharge), as well as spacing of Saddle supports. A penstock pipe of mild steel is proposed to be constructed. 3 numbers of Penstocks will feed 3 units individually. The optimum diameter has been determined by using various empirical relations. The Penstock is proposed to be kept exposed to the environment, duly supported over saddles and anchor blocks.

***3.4.7. Power house building*:**The power house will house all the heavy equipments and machinery systems. The Power House shall essentially comprise of the following bays:
1. The Machine Bay to house turbine and generator.
2. The Auxiliary Bay to accommodate auxiliaries, control room, store, office, pantry, toilet, etc.
3. The Service Bay for temporary storage and repairing of equipment.

***3.4.8. Hydro-turbine and Generator*:**In accordance to *Hydraulic Design of Small Hydro Plants*, *Alternate Hydro Energy Center, Indian Institute of Technology*, *Roorkee, 2011*, depending upon the head available at the site, the best suitable turbine for the Bichithur-Borgang project is the Francis Horizontal type of turbine. Three numbers of turbines of rated output 600kw has been proposed for the project.
The Generator used is a 3 phase, 50 Hz, 3.3kV synchronous generator of 750kVA with 10% continuous overload capacity coupled to Francis Turbine. It shall match with the turbine in respect of speed, runaway speed and moment of inertia, overload capacities, couplings and other requirements.
The generator shall be complete with Excitation System, Brake System, Lubricating System, Cooling Water System, Fire Protection etc. It will be provided with its individual control and protection equipment and system and is designed with adequate structural strength to withstand the runway speed of the turbine for 30 minutes without any damage. The generator shall be designed to continuously deliver 10% overload capacity without overheating.

Table 3. Salient features of the Small Hydro-power project

Location	
State	Assam
River	Sunani Stream, tributary of Borapani river
Longitude	92 degree 22' E
Latitude	26 degree 03' N
Access to the project	By road from Jagiroad, Assam.
Nearest Railhead	Jagiroad
Airport	Guwahati
Hydrology	
Catchment area	76.225 sq km
Maximum flow	26.713 cumecs
Minimum flow	0.131 cumecs
Weir	
Type	Trench
Shape	Trapezoidal
Length	15.0 m (by survey)
Width	Top- 2.25 m ; Bottom – 1.5 m
Bed slope	1 in 20
Feeder Channel	
Length	17.0 m
Shape	Rectangular
Size	Width 2.5 m; Height- 1.4 m
Bed Slope	1 in 200
Desilting Tank	
Length	45.0 m
Width	7.0 m
Depth	5.2 m
Head Race Channel	
Length	281.0 m
Shape	Trapezoidal
Size	Bottom width- 1.5 m; Top width - 2.5m; Height-1.5m
Forebay	
Size	Width; 10.0 m; Depth: 3. m (assumed)
Shape	Rectangular
Length	30.0 m
Storage capacity duration	2 min
Penstock	
Number	3
Diameter	1.1m
Thickness	4mm
Total length	55.0m
Design Discharge	2.40 cum/sec
Power House	
Type	Surface Power House, Stone masonry walls with RCC columns and beams with CGI sheet roofing.
Capacity	1.80 MW
Gross Head	30.0 m
Net Head	28.2 m
Annual Generation	4.24 MU (75% dependable flow)
Tail Race	
Shape	Rectangular
Size	Width-2.0 m; Depth- 1.6 m
Length	10.0 m
Financial Aspect	
Total project cost	Rs 1546.95 lacs
Cost / MW installed	Rs. 8.59 Crore
Levellised Tariff /Unit	Rs. 6.98

***3.4.9. Tail race channel*:**Turbine discharge shall be disposed off to the stream at downstream side by a Tail Race Channel.It is proposed to be constructed with stone masonry.

***3.4.10. Cost estimation*:**The capital cost of the project has been estimated at Rs 1546.95 Lacs.

***3.4.11. Salient features of the project*:**The salient features of the small hydropower project after designing is presented in Table 3.

4. Conclusion

This type of project are important to society because they help in all round development of remote areas thereby solving problems of unemployment , illiteracy, insurgency etc.Small hydropower projects while sharing all benefits of hydro-electric generation, harnesses a renewable source of energy in an environmental benign manner. Therefore, loss to healthy atmosphere of society is almost nil. Being small, it does not involve any submergence or violation of the sanctity of the forest. Availability of reliable electric energy is expected to reduce over dependence on nature and this will reduce depletion of fuel like forest wood, kerosene, cow-dung etc presently being used as domestic fuel by people in the area. The magnitude of the construction activity will not induce migration of labor to this area from other areas as local labor is available and thus local ecology will not be pressured.

Assam at present is suffering from a great shortfall of power supply. A large number of households in the state do not have electricity and use kerosene for lighting. Even for those areas, which are electrified, it is not uncommon to have 10 – 15 hours of blackouts every day.A policy for small hydro power development in the state up to 25 MW has already been drafted by the Govt. of Assam and is in the pipeline for implementation to attract Independent Power Producers (IPP).Thus, this type of projects can bridge the gap between demand and supply of electricity as it will enrich the central grid as well as uplift remote areas, thereby reducing poverty, unemployment and solve the problem of insurgency that Assam is facing now.

5. References

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