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Potential Assessment Of Small Scale/Micro Hydro Power For Rural Electrification And Specific Site System Design In Kafa Zone SNNPR region South Western Of Ethiopia

By

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DECLARATION

I, the undersigned, declare that this thesis entitled "Potential Assessment Of Small Scale/Micro Hydro Power For Rural Electrification And Specific Site System Design In Kafa Zone South Western Of Ethiopia" is my original work, and has not been presented by any other person for an award of a degree in this or any other University.

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Acronym

(KZoFED)Kafa zone Finance and Economy department

WB Woody Biomass

SNNPR south nation nationality people regional state

WHO world health organization

EEAEthiopian energy agency

asl,above sea level

CSA central statistics agency

Kwh killo watt hour

MHPmicro hydro power

m3/smetric cubic

MoWE ministry off water and energy

CFDcomputational fluid dynamics

AAltitude factor

BTemperature factor

Cpower factor

N=Number of days in the month

P=the target population at 20 years onwards,

P_{20}*= the current population, which is 150*6= 900*

R= the national annual population growth rate= 3% and

t,= the design period= 20 years

V Horizontal Vertical velocity on the settling basin

D SETTLING   Depth of the settling basin

W SETTLINGWidth of the settling basin

H_{g1}= *level difference between for bay and turbine shaft*

H_f= *hydraulic and friction loses in the penstock*

A =Altitude factor

B =Temperature factor

C =Power factor

ABSTRACT

Energy security and environmental protection are the major bottlenecks of development policies and strategies in developing countries. Renewable energy technologies especially Small/Micro

Hydropower (MHP) schemes have been identified as one of the best options for decentralized power generation in rural areas In this study MHP potential sites selection followed by intensive field survey was undertaken to technically and socio economically analysis of the power that would be generate and community load to avoid un match between power and the community population in the study area and to determine its feasibility for being constructed nearby feature

Ethiopia is situated in horn of Africa with a total population of 80 million of which 85% is living in rural areas where access to modern electricity is difficult, with electrification status negligible and being < 1% . These communities are settled farther away from the national grid and are sparsely populated which makes extending the national grid to them uneconomical because of the high cost of transmission and the very low load factor. However, improving the life style of the population as well as the economy of a country will be difficult without energy especially modern energy systems.

In the Millennium Development Goals of SSA and the Growth and Transformation Plan (increasing total electricity access from 41% in 2010 to 75% in 2015) of Ethiopia, increased access to modern energy in all sectors is one of the pillars. In most instances the possible role of small scale hydropower has been recognized, as in the new draft for energy strategy of the World Bank that does specifically highlight small scale hydropower as an important component of future World Bank activities in Africa Small Scale hydro power is recognized as one of the most viable sources of clean, renewable and abundant alternative energy resources for sustainable development in isolated rural areas of SSA countries

The socio-economic study indicated that social and economic situation of the HHs in the study area is well suited for community oriented development practice with more than 70% of the HHs having an annual income of more than $ 350/yr. Moreover, they currently have an energy expense of $18/year-$36/year for lighting only

Finally because of this research 6 potential sites are identified, so from this 6 potential site we can generate power 103.7kw and the total energy 2488.8wh /day means 2488800wh considering

per house hold consumption 82w From this potential sites 30,351 house hold or 182,107 people would be electrified this shows that the power that could be generated from each power plant site is more than enough of the load to be supplied and even it can supply for an increase in demand of at least 50% of today's demand. Except one sites at Hamani sites which not feasible for MHP, the remaining are taken to be a hydro-only system. The design discharge of the case study site is o.4 m3/s and net head is 13.5m the power that can be extract 34.4kw

Key words: ***hydropower, potential Assessment, micro hydropower, load Assessment, socio economics***

CHAPTER1. Introduction

1.1. BACKGROUND

There is a huge energy resource potential in Ethiopia, which, if utilized could minimize the present energy crisis prevailing in the country and enhance the process of rural electrification. The total exploitable renewable energy that can be derived annually from primary solar radiation, wind, forest biomass, hydropower, animal waste, crop residue and human waste are about 1,959x103 Tcal per year [1]. Out of this, the share of primary solar radiation is about 73.08 percent, and the share of biomass resources is about 12.8 percent [1].

Ethiopia is blessed with large hydro power resources. The gross hydro potential is estimated to be 650 TWh /yr [2]. Out of this gross potential, the economically feasible hydropower potential of Ethiopia has been estimated to be 15,000 MW to 30,000 MW. Of this economically feasible potential, only 10% or 1500MW to3000MW would be suitable for small scale power generation including Pico and Micro hydropower [1]. The recent baseline survey done for energy access projects reveals that the total theoretical potential for micro hydro development is 100 MW. When the regional distribution is looked up, some parts of Ethiopia have considerable hydro resources while others with semi-arid and arid climate have none.

The design flow of the plant must not exceed the minimum dry-season flow of the water resource. Stand-alone hydro schemes without alternative or back-up systems run the risk of insufficient capacity due to lower water. The micro hydro plant (180 kW) of Yaye (Sidama zone), which is recently built, has suffered from such difficulties during the dry season of 2002/03 [1].EPCO, the former national utility, used to install and operate a number of small hydropower stations in the micro and mini range. These were used to supply towns as self-contained system up to 1990s when demand exceeded their capacity especially during the dry season [2]. The interconnected system (ICS) was brought to these towns and the importance of the micro hydro systems was drastically reduced. As many of these micro/mini hydro systems date back to the 1950s and 1960s, they became unreliable and extremely costly to operate. Today, only one of these micro hydro plants is in regular operation

Access to modern energy is essential for the reduction of poverty and promotion of economic growth. Communication technologies, education, industrialization, agricultural improvement and water supply systems all require abundant, reliable, and cost effective energy access. With growing energy demand, rising imported fossil fuels costs, and environmental concerns, renewable energy is a financially intelligent investment. Ethiopia is endowed with several types of renewable energies.

Water is essential to all life. Human habitation has always developed where there have been accessible sources of water streams, rivers, springs, ponds and rainfall catchments. Water also used as a source of power. People have developed ways of raising water so that it can be moved to the point where it is required. Moving water contain energy corresponding to its speed and height. This energy can be utilized for different applications.

Micro hydropower system operate by diverting part of the river flow through a penstock (pipe) and a turbine, which drives a generator to produce electricity and the water flows back in to the river. This is preferable from an environmental point of view, as seasonal river flow patterns downstream are not affected and there is no flooding of valleys up stream of the system [21]. A further implication is that the power output of the system is not determined by controlling the flow of the river but instead the turbine operates when there is water flow. This means that complex mechanical governor system is not required which reduce cost and maintenance requirements. The system can be built locally at low cost, maintenance requirements and the simplicity gives rise to better long term reliability. Micro hydro systems are particularly suitable as remote area power supplies for rural and isolated communities without degrading the environment. It is estimated that in 1990 there was an installed capacity worldwide of small hydropower 19.5GW [10] Electrical energy can be obtained from a micro hydro system either instantaneously or through a storage system. The system provides 220Volts of AC power. In storage system, the micro hydro generator provides a constant DC charge to a battery system, via an inverter and the battery system must be sized to the daily electrical demand.

Micro hydro installations are widespread in ASIA, where there is a significant resource potential for further development. China, Nepal, Indonesia and Vietnam have well developed small hydro power industry with an installed capacity ranges from 1KW-100KW [23] The topography of these countries are ideal for micro hydro power, with high hills, scattered settlements and many rivers crossing these

Countries and such conditions make suitable for installation of turbines. Such turbines used to grind grain, hill rice and expel oil from oil seeds as well as the generation of electricity.

Ethiopia has a huge amount of water resource and suitable topography for hydro power technology. Oromia, SNNPR, Amhara, Benshangul and Gambella are suitable regions for micro hydro power development. [4]For power generation Ethiopia is mostly involved in large hydro plants. However , large hydro plants usually requires huge investment cost, long construction period and even after being finalized it may not be able to meet the demand. The grid is also expensive and difficult to reach the rural community due to topography of the country.

While micro hydro systems are manufactured locally and cost effective to meet the demand of the rural community specially off-grid rural house hold.

In addition to the above advantages micro hydro power has got the following benefits.

- Light source for off-grid rural household.
- Power source for irrigation activity and rural water supply.
- Power source for modern communication.
- Power source for mechanical application like milling and threshing.
- Source of income for the rural community.

As a cheap, renewable source of energy with negligible environmental impacts, micro hydropower technologies have an important role to supply energy, particularly in developing countries. It is an attractive alternative to diesel technologies in rural areas of developing countries as a means of achieving rural electrification

1.1.1. Classification of Hydro Power Plants

Four main aspects commonly used for classification of hydro power plants are:

- Design capacity(KW installed capacity)
- Design head
- Design type
- Grid type

1.1.1.1.

epending on design capacity hydropower can be divided:-

Table .1Classification of hydro power plants based on design capacity

Term	Power out put
Pico hydro power	<5000W
Micro hydro power	5-100KW
Mini hydro power	100-1000KW
Small hydro power	1MW-10MW
Full scale hydro power	>10MW

1.1.1.2. Based on design head again hydropower can be Classification by

According to many literatures

Low head plants H<15m

Medium head plants H=15 to 50m

High head plants H>15m

1.1.1.3. based on design type hydropower can be classified as:-

Run- off –the- river

Storage system

Run- off –the- river: - Most common type on the context of mini and micro hydro power

The diversion weir installed in the river causes minimum impact to the river as it has no impact on the seasonal flow pattern downstream of this structure

In some cases an enlarged fore bay serves as daily storage to cover daily peak demands

Storage system: - Not commonly used in the context of micro hydro power plant (complex design and expensive to implement)

Causes a large accumulation of water by flooding the valley upstream of it (large impact on the river ecology)

Seasonal storage and flood prevention (regulation of the river flow)

4. Based on grid type hydro power can be classified as:-

Off grid: - The micro hydro power supplies to non-grid by EEPCO, not interconnected with the national grid

On-grid: This is the mechanism of providing electric power to the main grid line

1.1.2. Micro-Hydro Schemes

The principles of operation, types of units, and the mathematical equations used in selection of micro-hydro power systems are essentially the same as for conventionalhydropower developments. However, there are unique problems and often the costs of the feasibility studies and the expenses of meeting all regulatory requirements make it difficult to justify micro-hydro power developments on an economic basis.

1.1.3 Components of the Micro Hydro Schemes

Weir: the weir acts to divert water through an opening in the river side into the open channels
Settling basin: it is used to remove sand particles from water
Channel: this part follows the counter of the hill side so as to preserve the elevation of the divert water
Fore bay: the water enters the tank which is called the fore bay tank to feed the water to the penstock.
Penstock: The penstock is connected at a lower elevation to a water wheel which is the turbine.

1.2 problem statement

Most of the people of Ethiopia (around 85 % of the population) live in rural areas where energy accessed 2% and 86% of urban resident accessed to electricity [5].The vast majority of Ethiopia's energy needs are met from natural sources. Nationally, biomass fuels constitute approx. 93% of the final energy consumption, with 77% being derived from woody biomass, 8.7% from crop residues and7.7% from dung.

In case of kafa Zone provided less electricity access, the consumption is much higher in Kafa; 1.9tone/hh/year [17] this leads to deforestation soil erosion, global warming and GHG emission Even if high potential of small scale hydropower in kafa zone still not exploited

1.3. Justification

True and lasting progress in socio-economic development relies on the preservation of natural resources. Environmental degradation in Ethiopia undermines development goals, threatens livelihoods and diminishes the quality of life. Most pressures come from energy demands for which no significant alternative sources is available especially for communities leaving in remote villages. Rural communities make about 85% of the total population and most of their live far from any modern source of energy depending on entirely on the natural resources (particularly forest) which is rapidity disappearing .

One of the challenges of the new millennium goal is to provide enough energy demands without widespread environmental damage. Activities which balance economic development with natural resource management and innovatinga healthy interface between energy demands and the environment are in the priority needs.

Development in rural communities is hindered not because of with lack of renewable natural energy sources, but because of lack of technology which can use natural energy sources to produce power. The following points sum-up the major justifications for the project research in the project area

- Lack of decentralized renewable energy supply system in the rural area.
- lack of the potential site to construct the small scale hydropower plant
- Lack of trained man power in the development of micro hydro power technology.

Potentials of such systems as an eye opener to the rural communities in terms of encouraging various services to the communities can be enumerated. For instance, the use of various appliances in village such as, TV, lighting, home appliances, productive use and institutions like clinics, schools, farmer training center and small work shop.

Regarding the energy source, it is recommended to use all energy resources available in the area. Where there is river near by the site and with sufficient water flow micro-hydro power is recommended due to low operational and maintenance cost as secure sustainability with reliable the current growth & transformation plan GTP (2010 – 2015) at national level planned to have of 65 MHP plants**[21]**

Due to constant stream flow and abundant topography mostly the potential site is located in the western and south west of the Ethiopia [23]. Renewable energy technologies especially Small/Micro Hydropower (MHP) schemes have been identified as one of the best options for decentralized power generation in rural areas [19]

1.4 Objectives of the study

1.4.1 General Objective:-

To exploit the potential site for a small /micro hydro hydropower for rural electrification specific site MPH system design

1.4.2 Specific Objective:-

- ✓ Assessment of micro-hydro power resources and collecting a preliminary data for small scale/ micro hydro power plant scheme design
- ✓ To analysis financial viability of the project at selected sites
- ✓ Local community load estimation for each site
- ✓ Analyzing design river flow rate
- ✓ Alternative energy technology promotion

1.5 Methodology

The methodologies to accomplish this thesis work were:-

Literature review: Published materials about mini and micro hydropower systems and assessment of hydropower potential of rivers will be studied.

Data collection: The data required for the potential assessment of rivers collected from the respective organization. For example, flow rate of the selected rivers is collected from the SNNPR regional water bureau from regional river potential assessment program and design head of the river and appropriate position for system installation is done from field work.

- Data analysis: The potential of each identified rivers analyzed from the collected data

1.6. Organization of the thesis

- This thesis work consists of five chapters.

The first chapter discusses the general overview of micro hydro power energy, its advantage and what cool energy is and its relevance both in the past and today. The selected sites for this thesis, the power of water and the way of utilizing it, statement of the problem, the objective of the study description of the study area as well as case study area and methodology are also presented in this chapter. Chapter two is a literature review part. In this chapter different literatures related to small/micro hydro plant energy issues both in developing and developed countries, the energy potential as a whole in Ethiopia specially the hydropower resources and more about MHP are briefly discussed. Including cross flow turbine efficiency Moreover, the methods used in the determination of head and flow rate of flowing rivers are covered in this chapter. The methodologies used while collecting data and the approaches applied while analyzing these data as well as while designing the scheme component design to determine the type and size of components used in each system are covered in chapter three.

Chapter four is all about the civil work design chapter five about electro mechanical chapter six is about electrical system for MPH chapter seven about driving system chapter eight is about mechanical component design chapter nine aboutElectrical load control chapter 10 power house planning chapter 11 cost evaluation and economic analysis chapter 12 about conclusion of the research

1.7. Description of the Study Area

1.7.1. Location, Area and Administrative Divisions

The Southern Nations, Nationalities and People's Region (SNNPR) is located in the Southern and South-Western part of Ethiopia. Astronomically, it roughly lies between $4^{o}.43$ - $8^{o}.58$ North latitude and $34^{o}.88$- $39^{o}.14$ East longitude. It is bordered with Kenya in South, the Sudan in South West, Gambella region in North West and surrounded by Oromiya region in North West, North and East directions.The total area of the SNNPR region estimated to be 110,931.9 Sq.Km which is 10% of the country and inhabited by a population According to CSA 20013 total population of SNNPR have a total population 17,836,302 out of this males 8,875,837 with 8,960,404 female and people live in urban 1,981,393 with 15,854,909 rural with 80002235 female &with 7,852673 Accounting nearly 20% of the total population of the country. The population density of the region became 142 persons per sq.k.m, which makes the region one of the most populous parts of the country.

The region is a multination which consists of about 56 ethnic groups with their own distinct geographical location, language, cultures, and social identities living together. These varied ethnic groups are classified in to the Omotic, Cushetic, Nilo-Sahara and Semitic super language families. Among which Omotic and Cushetic are the most populous and diversified ones with the largest areacoverage in region respectively. Based on ethnic and linguistic identities, the region is at present divided into 13 zones (sub-divided in to 126 Woredas) and 8 special Woredas, which further divided into3678 rural Kebeles. Regarding urban areas there are 22 town administration and 114 certified towns with municipal city status totally having 238 urban Kebeles. .

1.7.2 Location and Physical Features of Kafa Zone

Kafa Zone is one of the zones in Southern Nations, Nationalities and Peoples Regional State SNNPRS of Ethiopia. According to the KZoFED, Kafa Zone covers a total area of about 10,446.27 Km2 7.06% of the region and lies in 6º 15` to 8º 08` North latitude and 35º 30` to

36º 46` East longitude. The Zone is comprised of 10 Woredas (namely Adiyo, Bitta, Chena, Cheta, Decha, Gesha, Gewata, Gimbo, Saylem and Tello) and Bonga Town Administration.

Kafazone is a predominantly highland area with undulating landscape, mountains and rivers, forests, wide vegetation cover and wildlife. As Yihenew2003 indicated about one third of Kafa and the surrounding area is covered by montane rain forest comprising a rich mixture of species arranged in three or more stories. Kafa Zone has mean annual rainfall ranging between 1400 and 2000 mm and average annual temperature varying from 12 ºC to 26 ºC. It has three traditional agro-ecological zones such as cold zone Dega2500-3000 meters above sea level m.a.s.l, semi cold zone WoinaDega 1500-2500 masl, and hot zone Kolla 500-1500 masl. These zones comprised for 4%, 70% and 26% of the Zone respectively ZoFED.

1.7.3. Socio-economic Characteristics of kafa zone

The Zone has a total population of about 880,251 out of which 49.4% are males and 50.6% are females in 2007 CSA, 2008. People living in towns comprise 7.7% of the total population where as those living in rural areas are 92.3%. The average population density was 79 persons per square kilometer. Kafa Zone has total road coverage of more than 625.43 km out of which 306.65km is all weather roads. When this road coverage is compared with the total area of the Zone, the road density is 49.21 km per 1000km2. Sixteen towns in the Zone are getting digital and automatic telephone services whereas majority of the Kebeles have wireless telephone services. By this year, majority of the towns and the surrounding Kebeles have mobile telephone services. Kafa Zone has low drinking water coverage of 18.48% as reported in 2007 ZoFED.

The dominant economic activity in Kafa zone is sedentary agriculture with some shifting cultivation practice. The land use data of ZoFED shows that about 56% of the total area in Kafa is arable, whereas 29% is forest and bush lands followed by about 14% land under settlements and other purposes.

Since Kafa Zone has a suitable climate and fertile soil, it grows different crops and plants. Accordingly, maize, teff, sorghum, enset, millet, barley and wheat are the major food crops grown. Among the cereals, bean and peas are common. Coffee and tea are also grown mostly for cash. Kafa is also known for its production of different spices. Cattle, sheep, goats, poultry, donkeys, horses and mules are the major livestock kept by the farmers. The forest ecosystem makes an important contribution to the Livelihoods of people in the area in a variety of ways. The forests are the major sources of honeybee flora. The forest provides shade for the coffee and spices that thrive when protected from frost and direct sunlight. The forests also supply rural communities with fuel wood and timber, which they use both for household consumption and for sale

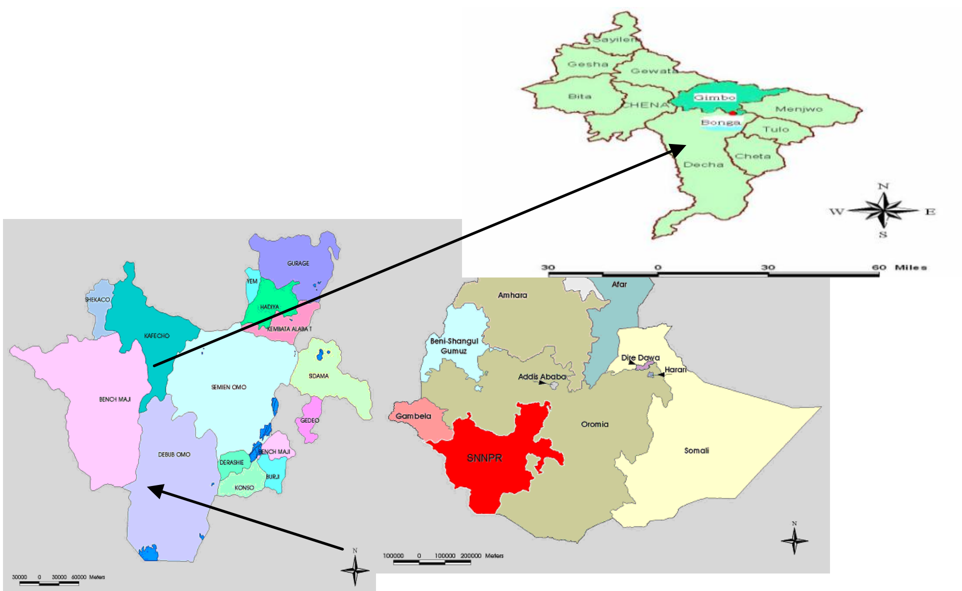


Figure 1 Map of Ethiopia (a) with SNNP Administrative Region (b) and the study area, Kafa Zone (c) (Source: Tewodros, 2008; Yonas, 2005).

1.8.Project Case Study area Bitta Woreda Shoshi River Micro Hydro Power Site

BittaWoreda is one of the ten Woredas of Kafa Zone. It is located at the western part of Kafa Zone (see Figure 1). The Woreda has an area of 1050.55 square kilometers, which comprised

9.45% of the Zone. It is located between 7º 12`35'' to 7º 33` 00'' North latitude and 35º 29` 15'' to 35º 51` 00'' East longitude. Bitta Genet town is the Woreda center, which is located at distance of 74km to the west of Bonga. All weather road from Jimma to Teppi passes through the Woreda. The Woreda is sub-divided into 24 rural Kebeles and a town administration. The elevation of the Woreda ranges from 1300 to 2569masl. Nearly 91%, 8%, and 1% of the Woreda has traditional agro-ecological characteristics of WoinaDega, Kolla, and Dega respectively. The mean annual rainfall is between 1220 and 1800mm and average annual temperature between 15 and 26 ºC. The soil type of the Woreda is mainly sandy and clayey with colors of black to brown and reddish brown.

Based on CSA 2013The Woreda has a total population of about **88,414** out of this people live in rural 84,776 from the total are with 41,976 males 42,799females according to the WoFED. Urban residents are 3638whereas the rural dwellers are 84776. The main ethnicities in the Woreda are Kafecho (the people of Kafa) (83.2%), Oromo (8.2%), Amhara (3.2%), and Bench (2.1%).

Chapter.2. Literature review

Most of the developing countries are suffering from what many call the energy crisis, characterized by depletion of locally available energy resources and dependence on imported fuel. In addition, the energy crisis is aggravating the food crisis by increasing the rate of deforestation and thereby causing degradation of farmlands. Furthermore, dependence on imported fuel is weakening the capacity of the concerned countries to buy food whenever the need arises. The fate of our country Ethiopia is not different from this issue. Ethiopia is a country with a population of above 80 million and a total area of 1.1 million sq.km. Of these 80 million people 85% is living in rural area where it is hard to get modern energy, electricity [4]. Therefore, these people are forced to use traditional energy sources for their demand. However, still there are people living in urban areas but relying on traditional fuels. This may be because that these people are not able to afford for the modern fuel and/or are unaware of the advantage that the modern fuels have over the traditional ones. With this in mind, Ethiopia is a country that relies extremely on traditional fuel, third from Africa, led by Chad and Eritrea. Moreover, more than 99.9% of the rural energy consumption of the country is mate by traditional fuels. The table below shows some examples of traditional fuel types and how much they contribute for the rural people.

B.TadeleChala and A.VenkataRamayya in 2012 researched on Characterization of Traditional Watermills for Upgrading to Small-Scale Hydropower Plants in Ethiopia the case of south western **Oromia also** the researcher performed the socio economic activity of the households around in the project area and they stated as the community is well suited for community oriented development practice with more than 53% of the HHs having an annual income of more than $ 405/yr. Moreover, they currently have an energy expense of $0.104/kwht for lighting service only. Technically, more than 76% of the water mills could be upgraded to deliver minimum of 10kw power and serve a 178% demand increase from the original situation. Finally, using this method of upgrading of traditional water mill to small scale hydropower minimum of 18% generation cost reduction could be achieved in using 52% of the civil work components in the watermill for the upgraded MHP scheme with complete replacement of the electro-mechanical components including the recommendation the potential assessment.

GTZ-ECO and Mining And Energy Agency in 2010 investigated potential assessment on prefeasibility study's to get the most feasible site which have the capacity of 10-20KW.And finally get four potential sites, from those sites they investigated comparison to differentiate which site very feasibly by technical and socio economical character compare and contrast the Finally the team proposes the **one site** for the pilot micro hydropower project which is to be implemented by the Mining and energy agency in cooperation with GTZ-ECO.

Nile basin capacity building in 2010 designed locally fabric able low cost cross flow turbine using different literature review and experienced person and reached appropriate cross flow water turbine prototype development and the preliminary prototype model has been fabricated at the college of engineering technology TDTC work shop preliminary tastes carried out in hydraulic laboratory to see the performance characteristics of turbine showed that the cross flow turbine work well in wider range of water flow. And the turbine performance graph showed that the turbine speed depends on water flow rate the higher the flow the higher the speed also direct related the power output of the turbine.

AbebeTilahun[2011] investigated potential assessment on micro hydropower in Ethiopian on specific river using primary data from field survey an secondary data from MoWE (ministry of water and energy) analysis of potential site power output and the number of beneficiaries are took in the researcher account also demand estimation of the selected site was analyzed and the researcher uses Homer software to simulate the output power

Anil Kunwor 2012 researched on Technical Specifications of Micro Hydropower using The field data required to design the civil components of the micro hydro project were derived from secondary data sources like row data from the village development committee as well as other independent project surveys. Similarly, system components designed in this study are intake structure, headrace canal to divert the water from the source, fore bay tank, sedimentation basin and the penstock assembly. Owing to the complexity and lengthy process of designing all of the system components; only these specific civil structures are designed in this study the system components that are designed are also illustrated with AutoCAD.

Power Plants HimaniGoyal ,M.Hanmandlu, and D.P.Kothari 2005 investigated the system of controlling the rotary motion of hydraulic turbine on small scale hydro turbines by controlling the rotary motion of spear valve for automatic control for continues control of flow and The suitability of servomotors for the control of small hydro power plants . Power can be controlled by controlling the rotary motion of the spear valve. In this research a flow control based model is proposed for the automatic control of small hydro power plants.

Korea marium university division of mechanical engineering in 2008 investigated that the effects turbine structure configuration on the performance and internal flow characteristics of the cross flow turbine model using CFD analysis and reach the result of the nozzle shape and runner blade angle and runner blade number are closely related to the performance and internal flow of the turbine.

Ethio Resource Group (2011)-National Energy Network: Energy for Growth and Transformation.). **Mentioned**the small scale hydro plant potential of Ethiopia is about 100 mw and the highly potential place for this potential is western Ethiopia Additionally; the current GTP (2010 – 2015) includes the installation of 65

Vineesh V, A. Immanuel Selvakumar December 2012 investigated the technical feasibility of a small hydropower plant for domestic use (micro-hydro), how it can be implemented in Valara waterfall, Kerala, India. Included an introduction to micro hydro system, design and simulation of hydraulic turbine and generator and how they apply specifically to power generation. The proposed site has a very large potential for power generation, yet the source of micro hydro energy remain un tapped

Caner AKCAN,Mahmut F.AKSIT and sendarAksoySabanci University 2006 designed low cost cross flow turbine runner that is compatible with mass production like an earlier study stress and weight optimization analyses had been presented for a common runner design also this paper includes analyses on segmented modular iteration. And the researchers used **Box Behnken** data tables have been used to obtain the response surface model also they analyzed of formulation for complex mechanical structure such as turbine rotor with multiple assemblies and the investigate on optimized factor of safety on critical components without violating the specified weight limits finally they attained factor of safety and frequency level.

Bilal Abdullah Nasir in February 2013 did Design of High Efficiency Cross-Flow Turbine for Hydro-Power Plant Researched on low head cross flow turbine to attain best efficiency of performance by optimization of total rotor design on different parts of cross flow turbine parameter's runner diameter, runner length, runner speed, turbine power, water jet thickness, blade spacing, number of blades, radius of blade curvature, attack angle and the blade and exit angles and finally the researcher attained the maximum efficiency 88%.

The Banki water turbine by C.A MOCKMORE Professor of civil Engineering and FRED MERRYFIELD Professor of civil Engineering in February 1949 designedlow head cross flow turbine this turbine consists of a nozzle and turbine runner the runner constructed from two parallel circular disks joined together at the rim with series of curved blades after construction of all turbine components they reached end result of good performance efficiency 68%and during laboratory test the Banki turbine shows operated on wider range of opening than most of turbine and maximum efficiency occur at a constant speed for all gate opening at constant head as well as the effective width of the wheel can be changed at will out changing the angle of attack.

European union energy initiative and Gtz in 2010 investigated the vast potential of small hydro power in Sub-Saharan African countries is one promising option to cover increasing energy demand and to enable electricity access for remote rural communities.. Also some successful MHP demonstration projects exist that can be the foundation for up-scaling initiatives.

Power Plants HimaniGoyal , M.Hanmandlu, and D.P.Kothari 2005 investigate the system of controlling the rotary motion of hydraulic turbine on small scale hydro turbines by controlling the rotary motion of spear valve for automatic control for continues control of flow and The suitability of servomotors for the control of small hydro power plants . Power can be controlled by controlling the rotary motion of the spear valve. In this research a flow control based model is proposed for the automatic control of small hydro power plants.

Korea Marium University Division of Mechanical Engineering In 2008 investigated that the effects turbine structure configuration on the performance and internal flow characteristics of the cross flow turbine model using CFD analysis and reach the result of the nozzle shape and runner blade angle and runner blade number are closely related to the performance and internal flow of the turbine.

Nile basin capacity building in 2010 designed locally febricula low cost cross flow turbine using different literature review and experienced person and reached appropriate cross flow water turbine prototype development and the preliminary prototype model has been fabricated at the college of engineering technology TDTC work shop preliminary tastes carried out in hydraulic laboratory to see the performance characteristics of turbine showed that the cross flow turbine work well in wider range of water flow. And the turbine performance graph showed that the turbine speed depends on water flow rate the higher the flow the higher the speed also direct related the power output of the turbine.

Anil Kunwor2012 studied on Technical Specifications of Micro Hydropower using The field data required to design the civil components of the micro hydro project were derived from secondary data sources like row data from the village development committee as well as other independent project surveys. The micro hydro designed in this study was of "run-of-the river" type. Similarly, system components designed in this study are intake structure, headrace canal to divert the water from the source, fore bay tank, sedimentation basin and the penstock assembly. Owing to the complexity and lengthy process of designing all of the system components; only these specific civil structures are designed in this study.. Wherever possible, the system components that are designed are also illustrated with AutoCAD.

Caner AKCAN,Mahmut F.AKSIT and sendarAksoySabanci University 2006 designed low cost cross flow turbine runner that is compatible with mass production like an earlier study stress and weight optimization analyses had been presented for a common runner design also this paper includes analyses on segmented modular iteration. And the researchers used **Box Behnken** data tables have been used to obtain the response surface model also they analyzed of formulation for complex mechanical structure such as turbine rotor with multiple assemblies and the investigate on optimized factor of safety on critical components without violating the specified weight limits finally they attained factor of safety and frequency level.

Bilal Abdullah Nassir February 2013 Design of High Efficiency Cross-Flow Turbine for Hydro-Power Plant Researched on low head cross flow turbine to attain best efficiency of performance by optimization of total rotor design on different parts of cross flow turbine parameter's runner diameter, runner length, runner speed, turbine power, water jet thickness, blade spacing, number of blades, radius of blade curvature, attack angle and the blade and exit angles and finally the researcher attained the maximum efficiency 88%.

The Banki water turbine by C.A MOCKMORE Professor of civil Engineering and FRED MERRYFIELD Professor of civil Engineering in February 1949 design low head cross flow turbine this turbine consists of a nozzle and turbine runner the runner constructed from two parallel circular disks joined together at the rim with series of curved blade safter construction of all turbine components they reached end result of good performance efficiency 68%and during laboratory test the Banki turbine shows operated on wider range of opening than most of turbine and maximum efficiency occur at a constant speed for all gate opening at constant head as well as the effective width of the wheel can be changed at will without changing the angle of attack.

C. B. Joshi,' V. Seshadri, 2 and S. N. Singh3 in 1995 investigatean experimental study on cross flow turbine parametric for better performance turbine the study observed that the efficiency of the turbine increases with increase in blade number, nozzle entry arc, and head. The present investigation has also shown that there is an optimum number of blades for a given nozzle entry Arc beyond which the performance of the cross-flow turbine deteriorates also been shown that cross-flow turbines at higher heads do not behave as pure impulse turbines

Young-Do CHOI, Jae-Ik LIM You-Taek KIM and Young-Ho LEE industry-Academic Cooperation Foundation, Korea Maritime University in 2008 investigated the effect of the turbine's structural configuration on the performance and internal flow characteristics of the cross-flow turbine model using CFD analysis. After the analysis they got results show that nozzle shape, runner blade angle and runner blade number are closely related to the performance and internal flow of the turbine. Moreover, air layer in the turbine runner plays very important roles of improving the turbine performance

Loice Gudukeya[1], IgnatioMadanhireUniversity of Zimbabwe, **Department of Mechanical Engineering** investigated on efficiency improvement of peloton wheel and cross flow turbines in micro hydropower plants case study revealed that turbines of better efficiencies can be manufactured, made available for MHS and the projects remain financially viable. This was achieved through the comparison of current fabrication methods used locally to methods used by different suppliers of turbines. Even though the better efficiency turbines are more expensive than the ones being used currently the overall benefit is clear. More electricity is generated hence the cost per unit kW actually decreases making the projects even more viable.

The financial viability of a project was determined by the project cost per kilowatt produced. Use of better efficiency turbines will make it possible to harness more electrical power from the same resources and recommended for feature work on experimental investigation flow friction effect on the hydraulic efficiency of a peloton turbine as well as considering materials which can be locally sourced for fabric able of the MHS in the country.

1Jusuf Haurissa, 2Slamet Wahyudi, 2Yudy Surya Irawan, 2Rudy Soenoko 2012 Investigated by concentrating on the The Cross Flow Turbine Behavior towards the Turbine Rotation Quality, Efficiency, and Generated Power and research deduce that power production The turbine power without implementing the guide passage with second stage comparing with the overall turbine power production by implementing the guide passage on the second stage also and the overall turbine power by implementing the guide passage with gate vanes on the second stage produces power investigating all this points and conclude that:-

The turbine efficiency without the guide passage less efficient than the turbine efficiency using the guide passage and the turbine efficiency with a guide passage less efficient than a guide passage with gate vanes, the experimental figure from the research shows that

The turbine efficiency without the guide passage is about 61.451 %, Furthermore, the turbine efficiency using the guide passage is about 71, 236% and the turbine efficiency using a guide passage with gate vanes, increase to 72.569%. Finally, there is an11, 118 % (72,569 % - 61,451 %) increase of the turbine efficiency.

Bilal Abdullah Nasir,inHawijah Technical Institute, Kirkuk, Iraq in 2013 investigate a research to obtain a cross-flow turbine with maximum efficiency, by including all the design of the parameters of cross-flow turbine by calculating all parameters at maximum efficiency including runner diameter, runner length, runner speed, turbine power, water jet thickness, blade spacing, number of blades, radius of blade curvature, attack angle and the blade and exit angles. Finally he obtained best performing cross flow turbine which is compatible for the low head small scale hydropower energy generation for rural electrification

Y D Choi[1], H Y Yoon[1], M Inagaki[2], S Ooike[2], Y J Kim[3] and Y H Lee[4] investigated studied on the effect air layer in the turbine chamber on the performance and internal flow the cross flow turbine and suggested a newly developed air supply method. Also, they conducted the field test and measured the power output using a new air supply method and CFD analysis on the performance and internal flow of the turbine is conducted by an unsteady state calculation using a two-phase flow model in order to embody the air layer effect on the turbine performance effectively The result shows that air layer effect on the performance of the turbine is considerable The air layer located in the turbine runner passage plays the role of preventing a shock loss at the runner axis and suppressing a recirculation flow in the runner.

The location of air suction hole on the chamber wall is very important factor for the performance improvement. Moreover, the ratio between air from suction pipe and water from turbine inlet is also significant factor of the turbine performance.

Je s ´us De Andrade, Chr i stian Cur iel, FrankKenyer y, or landoAguill ´on, Au r i s t e l a V ´asquez, a ndMiguelAsuaje Studied on the numerical analysis of the internal flow in a hydraulic cross-flow turbine type Banki. A 3 D-CFD steady state f low simulation has been per formed using ANSYS CFX codes. Their

Simulation includes nozzle, runner, shaft, and casing. The turbine has a specific speed of 63 (metric units), an outside runner diameter of 294 mm. Simulations were carried out using a water-air free surface model and k- ε turbulence model.

No	Author	Work performed	Methodology	Result obtained
1	B.TadeleChala and A.VenkataRamayya in 2012	Characterization of Traditional Watermills for Upgrading to Small-Scale Hydropower Plants in Ethiopia as a case study South West Oromia	On site data collection	The socio economic activity of the households around in the project area was calculated and found more than 53% of the HHs having an annual income of more than $ 405/yr. Energy expense of $0.104/kwht for lighting service only. Technically, more than 76% of the water mills could be upgraded to deliver minimum of 10kw power and serve a 178% demand increase from the original situation Finally. Recommended potential assessment on for rural electrification
2	GTZ-ECO and Mining And Energy Agency in 2010	investigated potential assessment on prefeasibility study's to get the most feasible site which have the capacity of 10-20KW	On site data collection	Finally they goat four potential site and made comparison on feasibility both by technically and socio economically and reached on conclusion with site feasibility both with the available head and river discharge in dry season finally the research team propose one pilot micro hydropower project which is to be implemented by the Mining and energy agency in cooperation with GTZ-EPCO

3	Nile basin capacity building in 2010	Researched on Design of locally fabric able low cost cross flow turbine using different literature review and experienced person	Using different literature review	Reached appropriate cross flow water turbine prototype development and the preliminary prototype model has been fabricated at the college of engineering technology TDTC work shop in university of Dareselam preliminary tastes carried out in hydraulic laboratory to see the performance characteristics of turbine the turbine speed depends on water flow rate the higher the flow the higher the speed also direct related the power output of the turbine. and the speed of the turbine is 205 rpm when the tank is full when the amount water in the tank is reduced the turbine speed is reduced t110 rpm finally they recommend parametric studies and improvement in various parameters for better performance the locally cross flow turbine .
4	**AbebeTilahun [2011]**	investigated potential assessment on micro hydropower in Ethiopian on specific river	data from field survey and secondary data from MoWE	Analyzed of potential site power output and the number of beneficiaries are took in the researcher account also demand estimation of the selected site was analyzed and the researcher uses Homer software to simulate the output power finally he recommend to exploit many sites to assist the rural electrification

5.	Anil Kunwor 2012	researched on Technical Specifications of Micro Hydropower	Field data collection and Autocad software	He designed the civil components of the micro hydro project were derived from secondary data sources like row data from the village development committee as well as other independent project surveys system components designed in this study are intake structure, headrace canal to divert the water from the source, fore bay tank, sedimentation basin and the penstock assembly
6	HimaniGoyal M.Hanmandlu, and D.P.Kothari 2005	investigate the system of controlling the rotary motion of hydraulic turbine on small scale hydro turbines		By controlling the rotary motion of spear valve for automatic contr continues control of flow Power can be controlled by controlling the motion of the spear valve. In this research a flow control based mod proposed for the automatic control of small hydro power plants.
7	Korea marium university division of	investigated that the effects turbine structure configuration on the	Using CFD analysis	Reach the result of the nozzle shape and runner blade angle and runner blade number are closely related to the performance and internal flow of the turbine.

	mechanical engineering in 2008	performance and internal flow characteristics of the cross flow turbine model using CFD analysis		
8	(Ethio resource group2011)	Small scale hydropower potential assessment		Concluded as the total potential as potential of Ethiopia is about 100mw and the highly potential place for this potential is western Ethiopia. Additionally; the current GTP (2010 – 2015) includes the installation of 65 MHP plants (Ethio Resource Group (2011):
9	CanerAKCAN, MahmutF.AKSIT and sendarAksoySabanciUniversty 2006	designed low cost cross flow turbine runner that is compatible with mass production like an earlier study stress weight optimization		analyses had been presented for a common runner design also this paper includes analyses on segmented modular iteration also they analyzed of formulation for complex mechanical structure such as turbine rotor with multiple assemblies and the investigate on optimized factor of safety on critical components without violating the specified weight limits finally they attained factor of safety and frequency level.
10	Bilal Abdullah Nasir in February 2013	Researched on low head cross flow turbine to attain best efficiency of performance by optimization of total rotor	CFD simulator	Attained High Efficiency Cross-Flow Turbine for Hydro-Power Plant finally the researcher attained the maximum efficiency 88%.

		design on different parts of cross flow turbine parameter's		
11	C.A Mockmore Professor Of Civil Engineering And Fred Merryfield Professor Of Civil Engineering In February 1949	design of low head cross flow turbine		the turbine consists of a nozzle and turbine runner the runner constructed from two parallel circular disks joined together at the rim with series of curved blades after construction of all turbine components they reached end result of good performance efficiency 68% .during laboratory test the Banki turbine shows operated on wider range of opening than most of turbine and maximum efficiency occur at a constant speed for all gate opening at constant head as well as the effective width of the wheel can be changed at wilh out changing the angle of attack.
12	European union energy initiative and Gtz in 2010	investigated the vast potential of small hydro power in Sub-Saharan African countries		Conclude as one of the promising option to cover energy increasing demand and to enable electricity access for remote rural communities. With some successful MHP demonstration projects exist that can be the foundation for up-scaling initiatives.

13	Vineesh V, A. Immanuel Selvakumar December 2012	investigate the technical feasibility of a small hydropower plant for domestic use in India including an		hydro system, design and simulation of hydraulic turbine and generator and how they apply specifically to power generation
14	C. B. Joshi,' V. Seshadri,2 and S. N. Singh3 in 1995	**Investigate**an experimental study on cross flow turbine parametric for better performance turbine the study observed that the efficiency of the turbine increases with increase in blade number, nozzle entry arc, and head		Investigated and reached to an optimum number of blades for a given nozzle entry Arc
15	Young-Do CHOI, Jae-Ik LIM You-Taek KIM and Young-Ho LEE	the effect of the turbine's structural configuration on the performance and internal flow characteristics of the	CFD Analysis	Result shows that nozzle shape, runner blade angle and runner blade number are closely related to the performance and internal flow of the turbine. Moreover, air layer in the turbine runner plays very important roles of improving the turbine performance

	2008 investigate	cross-flow turbine model using CFD analysis		
16	1Jusuf Haurissa, 2Slamet Wahyudi, 2Yudy Surya Irawan, 2Rudy Soenoko 2012	The Cross Flow Turbine Behavior towards the Turbine Rotation Quality, Efficiency, and Generated Power	Cfd analysis	Reach 1. to the result The turbine power without implementing the guide passage with second stage comparing with the overall turbine power production by implementing the guide passage on the second stage 2.The turbine efficiency without the guide passage less efficient than the turbine efficiency using the guide passage and the turbine efficiency with a guide passage less efficient than a guide passage with gate vanes,

Table.2 short summery of literature review

CHAPTER. 3 .METHODOLOGY AND APPROACHES

This chapter deals with the methodologies used for data collection both during field work and in hawasa from SNNPR State water bureau The data analyses as well as community load estimation are also presented in this chapter. It also covers design of some civil work and electromechanical components required for the selected hydro sites.

3.1 METHODOLGY and source of data Collection

primary data are those collected by the direct involvement of the researcher for the purpose that is intended to be done, may be conducted during field survey. During field survey, primary data is collected through direct measurement (of the head) of each river, interview with the local people (of the number of households nearby the rivers and the average number of people per household and, the type of loads they may use). For the village around **Shoshi River,** called yina there are 150 households. With 2 churches but because the area is not suitable for irrigation, irrigation pumps are not assumed. Therefore, the loads which are considered in this area are only home loads.

3.1.1. On site data collection stream flow measurement

Velocity area method or floating method is simple to analyze the discharge of the river

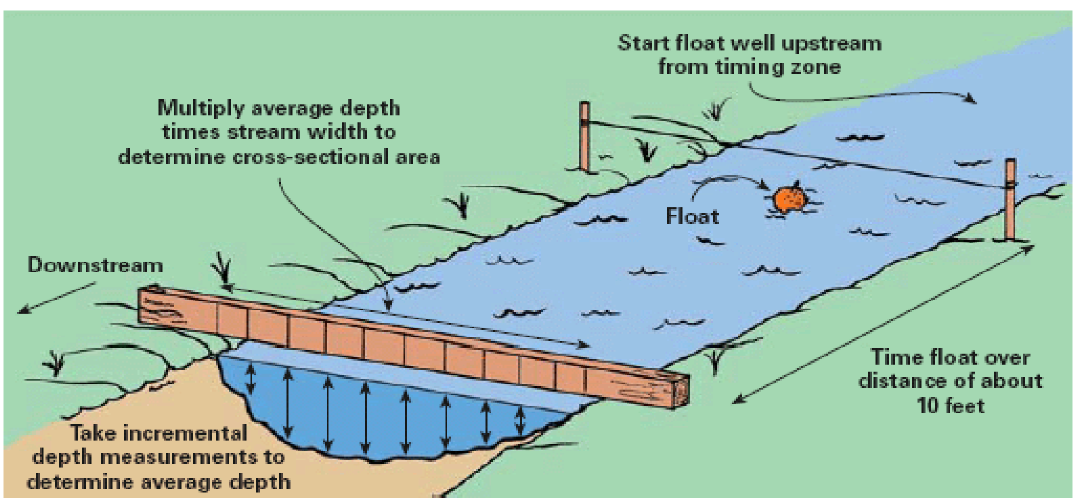


Fig 2.On site data collection method using velocity area method

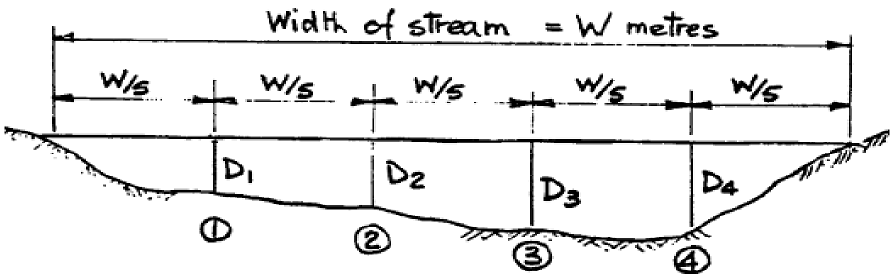


Fig-3:-River depth and width measurement procedure [21]

Depth	**W**	Time	Length	Correctional Area	velocity
D1=0.32		T1=35.9	L =11m		V=L/tav
D2=0.46		T2=33.4			
D3=0.51		T3=36.6			
D4=0.56		T4=30.7			V=0.32m/s
D5 =0.62	**W =5**	T5 =32		A=Dav*W	
D6=0.54		Tav=33.7		A=2.35	
D7=0.45					
D8=0.36					
D av=0.47	**Q=A*V*C =/s if 70% is diverted , 0.39 ≈ 0.4 m^3/s, c=0.8**				

Table.3. Shows the Data Collected from yina Site and the shosha River Discharge at Mid-Day of October

3.3 .POWER OUT PUT ESTIMATION

The potential of the river to produce power is mainly depends on the discharge, the head of the river and the efficiency of the turbine and the generator mathematically it is expressed as

P = η *H *Q *ρ*g = 0.65*13.5m*0.4m$^{3/}$se*1000*9.81

=34.4kw

Fig.4 fig.4.hamani site assessment

Fig.5 dadati MHP site On site data

Fig.6.the former grain grinding mill

with Wooden penstock

In addition to the onsite measured primary data we used regional water bureau potential assessment data of each selected /exploited sites so by compare and contrasting the annual minimum discharge of the river that are measured with dry season to avoid seasonal fluctuation of the rivers discharge analysis should be analyzed in dry season under consideration of all the above facts we assessed 6 potential site through 5 woredas next to the potential assessment as a case study potential site scheme design gooses to one specific potential sites

3.4 The exploited sites during potential assessment:-

Project that exploited during the project

1.Decha Woreda (Meligawikebele)

Site Name:-Melligawi Micro Hydropower Site

Distance from Bonga 55km

Distance from Grid Area 10km

The site is 30km from bonga town the settlement of the people in not that Mach scattered also the site have enough discharge with good head

Q = 0.23m3/s 230l/se H= 9mThe power that can generate from the site using Using T-12 turbine (efficiency ε = 65%) GPS location:

E= 1824 m a.s.l

37N 0189055

UTM 0773849 directions

The power that can generate

$$P = \varepsilon\gamma QH = 0.65 * 9810 * 0.234 m^3/s * 9m = 13199 watt = \underline{13.1 Kw}$$

2. Gesha woreda (Didifa Kebele)

GPS location

36N 0804498

UTM 083698

Elevation=2152 m

Site Name:-dadati micro hydro power

Distance from bonga 84 km

Distance from main grid 11km

The main river has a discharge of about 290 l/s,0.29m3/s by diverting the river completely We can generate power using the formula

$$P = \varepsilon\gamma QH = 0.65 * 9810 * 0.29m^3/s * 11.4m = 21kw$$

3. Gesha Woreda (Kico) Kebele

The second site in the same place gesha woreda is the former traditional water mill site:-

Site name dadati micro hydro power site

GPS location

36N 0804526

UTM 0837144

E= 2164m

$$P = \varepsilon\gamma QH = 0.65 * 9810 * 0.173m^3/s * 10.8m = 11.9kw$$

This site was the former traditional weir site but at this time the site is out of any function due to problem of the community leader during mobilization to buy the maintenance material for grinding mill after community discussion for the project site to construct micro hydro power plant in place of former grinding mill due to the problem of electrification critical together with price of kerosene highly increased day to day Whereas, the diverted canal has 173 l/s flow rate. To divert the river they constructed a traditional weir the watermill site can be modified to give 12m head & upgrading therefore bay location & penstock gives a good power output. . It has a good slope & 12m head. Thus, if use a T-12 turbine (efficiency $\varepsilon = 65\%$) by considering 90% net head

4. **Gimbo Woreda (Geshi River Girwakebele)**

Site Name:geshi river micro hydro site
Distance from grid 11km
Distance (From Bonga): 45km

GPS location:

37N 0199985 and

UTM UTM=0814975

E= 1758m a.s.l
Discharge of the river Q=0.24m3/s

Hg=8m, Hn=7.2m

The power that can be generated:-
Thus, if we use a T-12 turbine (efficiency $\varepsilon = 65\%$)

$$P = \varepsilon\gamma QH \quad =0.65*9810*0.24m3/s*7.2m=11kw$$

The site has a good access of transportation which is available at all seasons. The village is out of grid line. I.e. since it is in remote area the village couldn't get electricity from EEPCo in near future. Around the site, the settlement of the community is also attractive. Local construction materials are available at the site.

5. **Gimbo Woreda Hamani Kebele**

Site name: - wosha river micro hydro power site
DiStance from bonga 35km from capital bonga
Distance from main grid area 7km

GPS location

37N 0201158

UTM 0813681

E=1796m

People living in the kebele is highly scattered and also the river design flow rate together with available head is that much not attractive promising

Q=0.97m3/s

H=5.4 $P = \varepsilon\gamma QH$

The power that can be generate using if a T-12 turbine (efficiency $\varepsilon = 65\%$)

$P = \varepsilon\gamma QH$ p=0.65*9810*0.097m3/s*5.4m

P=3.3kw

The power that can generate from this site not sufficient to the people that so based on the potential assessment this site is not feasible

6 .Chena Woreda dukra Woshi Kebele Woshi River Micro Hydro Power Site

SITE NAME: - Woshi River Micro hydropower site

Distance from bonga 58km

Distance from main grid area 20km from grid

GPS Location 37N UTM 0170804

0810211

E= 1732 m a.s.l

The power that can be generate using a T-12 turbine (efficiency $\varepsilon = 65\%$)

$P = \varepsilon\gamma QH$ p=0.65*9810*0.132m3/s* 9m

P=7.5kw

7. bita woreda yina kebele

Site Name:-shosha river micro hydro site

Distnce from Bonga:-110km

Distance from main grid 20km

GPS LOCATION: - 37N 0230666

UTM 0786913 E= 2618m a.s.l Q = 400 l/s = 0.4m3/s

The site has a good access of transportation which is available at all seasons. The village is out of grid line. I.e. since it is in remote area the village couldn't get electricity from EEPCo in near future. Around the site, the settlement of the community is also attractive. Local construction materials are available at the site. Yina site is a very good project site for Micro hydropower generation. The power that can be generate from the site using a T-12 turbine (overall efficiency $\varepsilon = 0.65\%$)

$P = \varepsilon\gamma QH$ p=0.65*9810*0.4m3/s*13.5m

=34.4kw

Table.5 Potential exploited sites summary

No	Site Name	Distance From bonga (Km)	Distance from gride line	Discharge (m^3/s)	Net Head(m)	Power output (KW)	Accessibility
1	**Shosha/yina**	**110**	**20km**	**0.4**	**13.5**	**34.4**	**Feasible**
2	Woshi	58	12	0.132	9	7.5	feasible
3	hamani	35	7	0.097	5.4	3.3	Not feasible
4	**Geshi**	**45**	**11**	0.24	**7.2**	11.866	**feasible**
5	Didifa	96	10	0.195	11.7	15.6	feasible
6	Kico	79	12	0.173	9	12.8	feasible
7	Guma	45	10	0.23	14	14.46	feasible

3.6 case study area profile

SHOSHI RIVER micro-hydro power site is located 110km from BONGA following the main road along MIZAN TEPPI. The site is located 20km from main road and hardly reachable by motor cycle during rainy season.

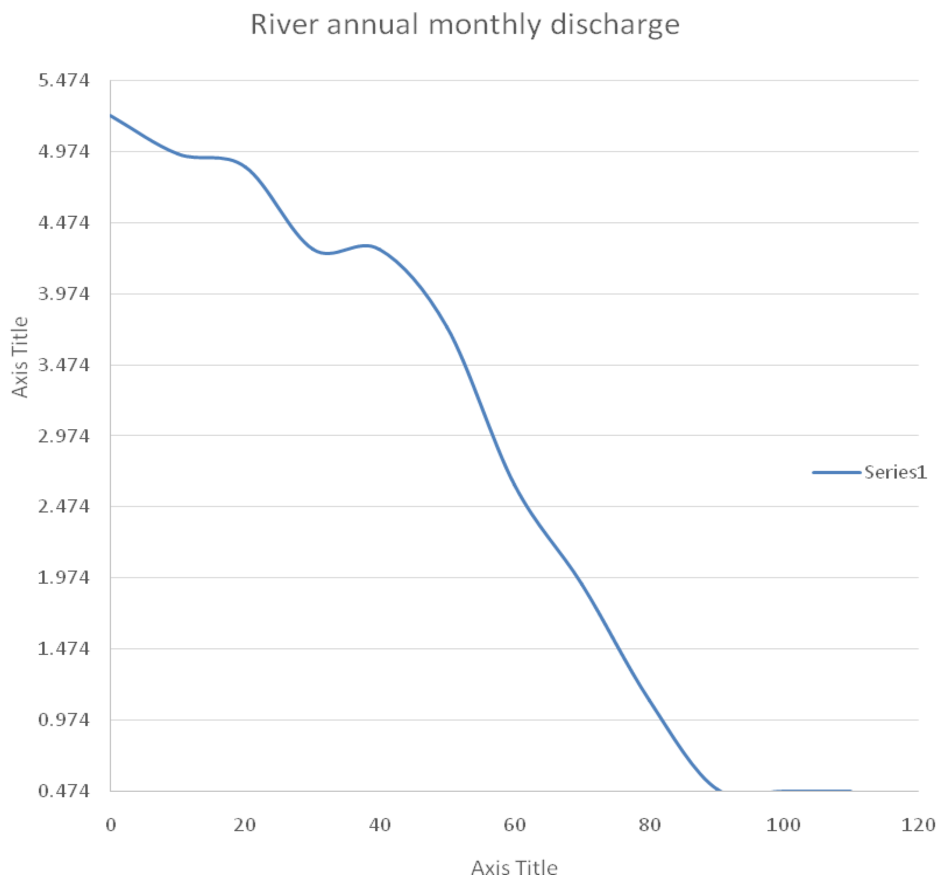
There are about three hundred households are living in three directions from the hydro power site. In the villages there are some government institutions like kebele administration, school, clinic and churches.

The source of living for the majority of the people is agriculture. These areas are known for their cash crops like coffee, chat and different fruits. Available energy sources are sunrays, water fall and bio-masses. At present the village has no electric light and the main grid far from the villages about 720km with difficult topography. There is a river called shoshi which is about 2km far from the villages which has a discharge of 400lt/sec during dry season. It is possible to generate a minimum of 32kw power to electrify the village. The river also has many suitable hydro power sites.

Now a days the villager consider the electric power no more as a luxury product reserved for big towns. Especially, in this time when diesel/ Kerosene prices getting higher and higher every day the demand for light is becoming a burning issue.

Analysis of Discharge of the catchment area using Barclay method from 15 year Mean annual rain fall data from Bonga metrology station

Time	Discharge
0	5.23
10	4.96
20	4.87
30	4.2869
40	4.286
50	3.74
60	2.63
70	1.93
80	1.11
90	0.49
100	0.476
110	0.474



3.6.1 Site location

The shoshi hydropower project is located 110 km from the kafa zone capital bonga.

GPS location 37N 0230666 UTM 0786913 E= 2618 m a...s.l

3.6.2 Case Study site Demand Assessment and Socio Economics Assessment

The Survey site is situated at 20 km away from Main Street to Teppi road where EEPCO line stops.The total population of Yina Kebeleis 4560. There are about 912Households around the envisaged hydro power station. Each House hold is expected to have 5 to 6 people. There are also some small villages close to the Village namely, Yina at 20 km, . In the village there is a first cycle school that has 7 buildings with 20 class rooms(1-4 class) at 1. 8 km distance with 640 students. For the village around **shoshi River,** called yina there are 150 households. With 2 churches but because the area is not suitable for irrigation, irrigation pumps are not assumed.

Therefore, the loads which are considered in this area are only home loads **shoshi micro hydropower**

The following design and analysis is based on the 15m gross head and minimum discharge $0.4m^3/s$ measured at Shoshi Micro Hydro Power Site.

1. Power output of the site

The power output of shosha micro hydro power site can be calculated as

$P_{el}=\rho*g*Q*H_n*\eta$ Where P_{el} = electrical power output in Watts

ρ = density of water (1000 kg/m3)

g = gravitational acceleration (9.81 m/s2)

Q = flow in 0.4 m3/s

H_n = net head in m (use 90% of gross head)η = overall efficiency (use 65%)

Therefore power output = 34.4KW

3.6.3 Case study area Design period

According to the guide lines for micro hydro power planning with due consideration of the

item	Sector	Activity	Unit	Quantity	Remark

government plan for rural electrification, the design period is fixed reasonably to be 20 years. Therefore, the current population is projected for 20 years with the national population growth rate, 3% and an assumption that a HH with average number of 6 members is applied for power demand estimation. Accordingly, the population (number of HHs) at 20 years is computed as follows:

$P20= P_0(1+n(r)^5$ ……………………………………………………………………..eq.3.5

$=150\ (1+20\ (0.03)^5)$ = 173 which shows the number of HHs to be expected is 2076/6= 346 HHs in the kebele Yina village

Where, P_{20}, the target population at 20 years onwards,

P_0, the current population, which is 150*6= 900

r, the national annual population growth rate= 3% and

t, the design period= 20 years.

3.6.4 Energy demand assessment and scheduling

For improved performance of domestic, public and commercial activities, ample electric energy should be available whenever required. In order to precisely estimate the power demand, all types of utilities and their application time, expected during project operation, have to be identified and quantified. Based on social- economic surveys, those listed below appliances with their respective quantities are considered for demand computation. The maximum power demand was found to be 28.3Kw. But the power generated is 34.4kw

1	Agriculture	Farming &Breeding	%	>95	Coffee,Chat, Enset
					is dominant
2	Industry and	water Wheel grinding	No		Not Functional
	trade	mill			Currently
		Diesel grinding mill	>>	1	
		Tea Houses	>>	3	
		shops	>>	No	
		cereal store	>>	No	
		weaving	>>	No	
3	Education	Kinder garter	>>	Nil	
		elementary School	>>	1	20 class rooms
		Junior School	>>	Nil	
4	Health	Health centre	>>	1	1 block
5	urbanization	Population (2007)	>>	5994	
		iron-Roofed houses		300	
		Sheka" or Bamboo houses		612	
		Kebele office		1	4 class rooms
6	Transport and	Transport type and	Isuzu	Nill	
	Communication	frequency	No		
		Telephone	No	1	
		Postal service	No	Nil	
		Bank	No	Nil	
7	Culture	Churches	No	2	

Table.6 .Socio economics activities of the case study site shosha micro hydro power Yina kebele

Table.7 Community load estimation and scheduling

	public services	Power rating	QNTY/ amount	Total power in kw	Consumption hour	Cons hour	Cons hour	Total energy consumption In kwh
I					day time	Night	total time	TOTAL
1	Residential room	11	346	3.806	2	6	8	30.448
2	street light	40	40	1.6	1	12	13	20.8
3	radio tape	15	346	5.52	12	5	17	93.84
4	refrigerator	180	10	1.1	12	12	24	26.4
5	TV	110	25	2.75	6	5	11	30.25
6	grinding mill	10000	1	10	6	2	8	80
7	Water pump	180	1	0.18	2		2	0.36
II	**health post**	0					**Sub total**	**282.1**

1	TV	110	3	0.33	12	6	18	5.94
2	refrigerator	180	2	0.22	12	12	24	5.28
3	street light	40	8	0.32	1	12	13	4.16
4	room lump	11	10	0.11	12	6	18	1.98
III	**elementary school**			0	0		**Sub total**	**17.36**
1	room lump	11	40	0.66	2	6	8	5.28
2	street light	40	20	0.8	1	12	13	10.4
3	TV	110	2	0.22	11	2	13	2.86
4	radio tape	15	2	0.03	6	2	8	0.24
5	refrigerator	110	2	0.22	12	12	24	5.28
IV	CHURCH						Sub total	**24.06**
1	Church lighting	25	16	0.4	1	12	13	5.2
2	Mega phone	10	2	0.02	4	3	7	0.14
				28.3			**Sub total**	**5.34**
							Grand total	**328.86**

Finally from this site we conclude that the maximum power 34.4kw *24h=825.6kwh the net Energy that generate from this site is by considering generation and transmission loss 8%

Then 34.4kw *0.08=2.75kw*24=66kwh here the net power is 34.4kw-2.75kw=**31.6kw**

Then by subtracting this loss from the total loss will be the net loss final

The net energy will be gross energy – generation and transmission loss considered, 825.6kwh-66kwh =**759.6kwh**

Table.8Catchment load profile

Time of the day	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Load profile in (kw)	**14.93**	**10.5**	**10.5**	**10.5**	**10.5**	**10.5**	**10.5**	**10.47**	**10.47**	**10.47**	**10.47**	**17.65**	**17.68**	**17.68**	**14.68**	**14.68**	**14.68**	**14.68**	**8.06**	**4.26**	**4.26**	**4.26**	**4.26**	**4.26**

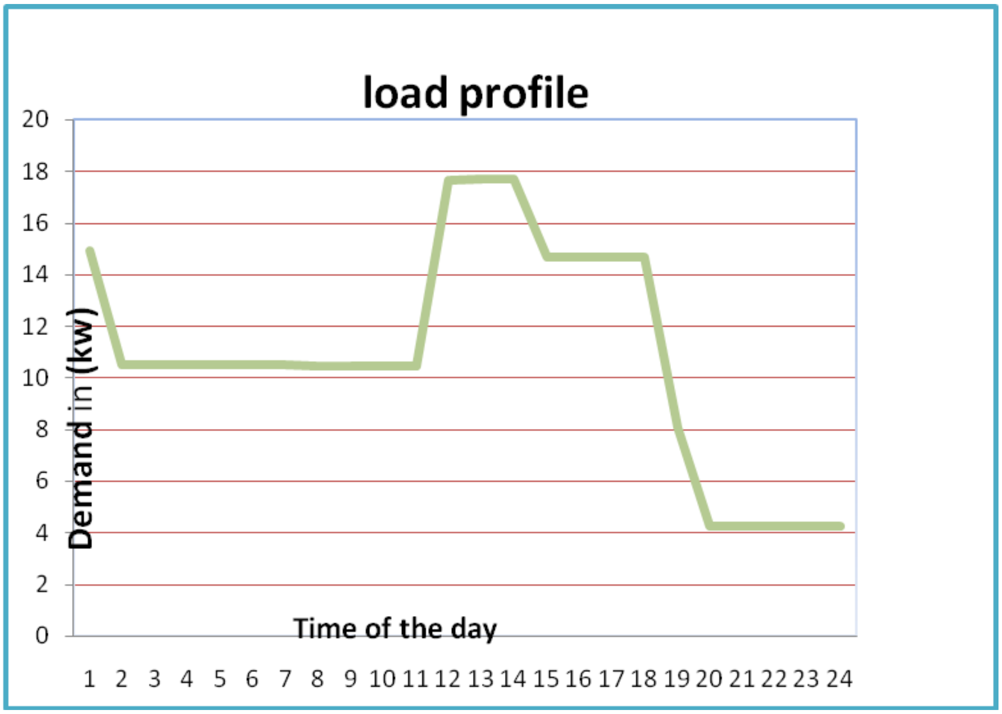


Fig.8 Catchment load profile calculated from catchment device load consumption

3.7 Civil work scheme design at case study sites

3.7.1 Plant scheme components design

3.7.1.1 Design of settling basin

The purpose of the stilling basin is to remove the suspended matter, which comes from the river and seriously damages the turbine. To remove a material the water flow must be slowed in silt basins so that the silt particles deposited on the floor level can be periodically flushed out to make room for further deposition.

The depth of the settling basin and its width together determine the horizontal velocity of the water flowing through it.

$$\mathbf{Q} = \text{Vhorizontal} * \text{Dsetling} * \text{Wsettling}$$

W SETTLING = 5 to 15 times width of cannel for most for bay design. Therefore we can take the width of the settling basin (SW) to be 5 times the canal width.

The length of settling basin could be computed from the following relationships:

$$\frac{\text{lsetling}}{\text{Dsetling}} = \frac{\text{Vhorizontal}}{\text{Vvertical}}$$ …………………………………………………………………. eq.4.1

$$\text{Lsettling} = \frac{Q}{\text{Wsetiling} * \text{V vertical}}$$ ………………………………………………………….eq 4.2

The depth of canal water is 0.25 meter and the silt basin at cannel entry

Q Design = 0.4m3/s

Design of Head race channel

Design of Head race channel :- the headrace canal carries the design flow from the intake to the fore bay. Generally, the canal runs parallel to the river at an ever-increasing difference in elevation, which gives the micro-hydropower system its head.

The canal cross section and alignment should be designed for optimum performance and economy in order to reduce losses due to leakage. It could be an open channel of efficient section to transport the water into the fore bay

.$Q = 0.4m^3/s \quad = 400l/s$

V=maximum velocity permissible =0.7m/s

Length of the channel L=1200m

Roughness coefficient n=0.022

Cross sectional dimension

$$\text{Area A} = \frac{Q}{V} = \frac{0.4}{0.7} = 0.57 \approx 0.6m^2$$

During civil work to be consideration

Top width

$Topwidth\ \mathrm{T} = 2\mathrm{d}$ ………………………………………………………eq.4.3

$\text{Area a} = \mathrm{T} * \mathrm{d} = 2d^2$……………………………………………………...eq.4.4

$\text{depth d} = \sqrt{\frac{0.6}{2}} = 0.5$

By providing free board of 15 cm

Design of settling basin

- Particle size limit – $d_{limit} = 0.2\text{mm (for low head power plants} - 0.2 \text{ to } 0.5\text{mm)}$
- Flow velocity v_d in sand trap must not exceed upper limit.

i.e. $V_d = 44\sqrt{d}$ ……………………………………………………………………eq.4.5

$V_d = 44\sqrt{0.2} \quad V_d = 19.7cm/$

$V_d = 0.2m/s$

- Width of setting basin - practically it is b/n 5 to 15 times the canal width

$canal\ width = 0.5m w = 5 * 0.5\text{m} = 2.5\text{m}$ $\text{length of setling basib L} = \frac{Q}{(W*V_S)}$…………eq.4.6

$V_d \text{sinking velocity (for d} = 0.2mm), then v_s = 0.028\frac{m}{s}$

$\text{L} = \frac{Q}{(W*V_S)}$ ………………………………………………………………………eq.4.7

$\text{L} = \frac{0.4}{(2.5 * 0.028)} = 5.7 \approx 6m$

$L_{entry} = L_{exit} = w = 2.5m.$ ………………………….......................eq.4.8

If the silt that are going to deposited through the canal water flow is 0.5kg/m^3

If 100% of the silt is deposited in the collection tank then:

$\text{rate of silt deposited} = \text{sit load} * \text{rated flow through the canal}$

$= 0.5 * 0.4 = 0.2\frac{kg}{s},$

the silt that deposited in different hour per day

$\text{silt deposited in 12 hour} = 12 * 3600\text{s} * 0.2\frac{kg}{s} = 8640kg$

Considering density of sand as 2600 kg/m3 and estimating the packing density of the deposit as 50% then:

To calculate the volume of silt that deposited in 12hour can be calculated as

$$\text{Volume of silt deposited} = \frac{8640kg}{(0.5 * 2600\frac{kg}{m^3}} = 6.6m^3$$

$$\text{Depth of the collection tank} = \frac{volume}{area} = \frac{6.6}{(2.5 * 3)} = 0.88m \approx 0.9m$$

$$\textbf{total depth} = \mathbf{0.9m}$$

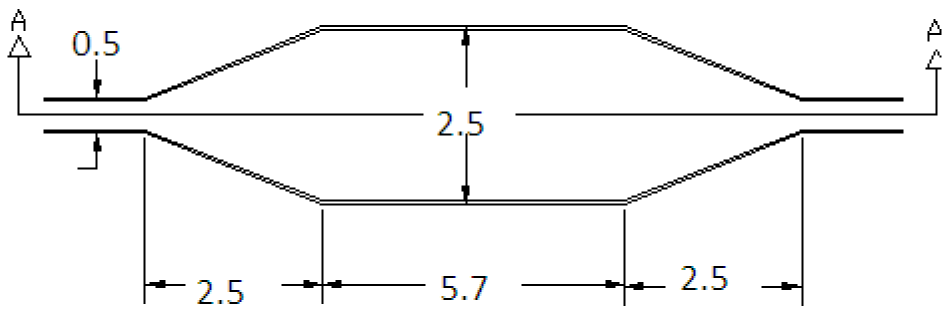


Fig shows the settling basin of the

3.7.1.2 Design of Head race channel

$\mathrm{Q} = \frac{400\mathrm{l}}{\mathrm{s}} V_d = 0.2m/s$ Length of the channel $\mathrm{L} = 1200\mathrm{M}$

Type - unlined earth with roughness coefficient $\mathrm{n} = 0.02$

Max velocity permissible through the channel

$\mathrm{v} = 0.7\mathrm{m/s}$Cross sectional dimension$\mathrm{Area} = \frac{Q}{V} = \frac{0.4}{0.7} = 0.57 \approx 0.6m^2$

From economic consideration;

$Topwidth\ \mathrm{T} = 2\mathrm{d}\mathrm{Area}\ \mathrm{a} = \mathrm{T} * \mathrm{d} = 2d^2$

depth $d = \sqrt{\frac{0.6}{2}} = 0.5$ by Providing free board of 15 cm

$Total\ depth\ \mathrm{D} = 0.5\mathrm{m} Base\ width\ B = \mathrm{T} = \mathrm{d} * 2 = 0.5 * 2 = 1\mathrm{m}$

Hydraulic radius $\mathrm{R} = \frac{Area}{perimeter} = \frac{(0.5*1)}{(1+2*0.5)} = 0.3m$ ………………..eq.4.9

To calculate the Slope of head race from (manning's equation)

Channel bed slope $= \mathrm{S} = \left(\frac{nV}{R^{2/3}}\right)^2$ ……………………………………….eq.10

Channel bed slope $= \mathrm{S} = \left(\frac{0.02 * 0.7}{0.3^{2/3}}\right)^2 = 0.000976$

$head\ loss = bed\ slope * Length\ of\ channel$

$= 0.00976 * 12m = 1.17m$

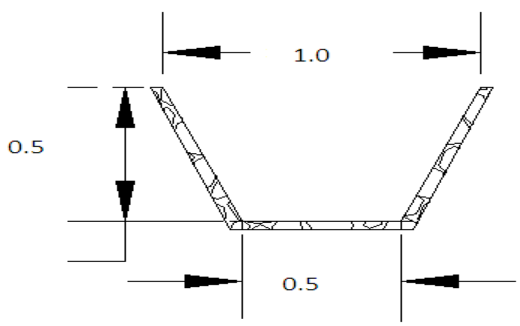


Fig. shows head race channel of the site

3.7.1.3 Design of fore bay tank

The fore bay tank connects the channel and the penstock. The tank allows fine silt particles to settle before the water enters the penstock.

A fine trash rack is used to cover the intake of the penstock to prevent debris and ice from entering and damaging the turbine and valves.

- Water depth in the headrace channel $\mathrm{d} = 0.5m$
- Width of head race channel $= 0.6m$
- Particle size limit $d_{limit} = 0.2mm$
- $flow\ velocity\ v_d$ in sand trap must not exceed upper limit.

$V_d = 44\sqrt{d}$

$V_d = 44\sqrt{0.2}$

$V_d = 19.7cm/$

$V_d = 0.2m/s$ Width of setting basin = by taking w = 2m

$$\text{Length of settling basin } = \text{L} = \frac{Q}{(W * V_{S)}}$$

$$V_S = \text{sinking velocity } V_S = 0.028\frac{m}{s} = for\ d = 0.2mm$$

$$\text{L} = \frac{0.4}{(2 * 0.028)}\ \ \text{L} = 7\text{m}$$

$$L_{entry} = L_{EXIT} = \text{W} = 2\text{m}$$

- Collection tank capacity
- Rate of silt deposited = silt load * rated flow through the canal

$$= 0.5 * 0.4\frac{m}{s} = 0.2\frac{kg}{s}$$

$$\text{Silt deposited in 12 hours } = 12 * 3600\text{s} * 0.2\frac{kg}{s} = 7512.5kg$$

By taking the density of sand as 2600 kg/m3 and estimating the packing density of the deposit as 50% then:

$$\text{Volume of silt deposited} = \frac{7512.5}{(0.5 * 2600)} = 5.8m^3$$

$$\text{Depth of the collection tank } = \frac{volume}{area}$$

$$\frac{volume}{area} = \frac{5.8}{(2 * 6.2)} = 0.5$$

3.7.1.4 Water storage

The fore bay tank must have a minimum storage volume to accommodate rapid change of turbine flow without excessively lowering for bay water level and introducing surge waves in to the headrace channel.

During for bay/temporary storage of water design of small /MHP system we have to consider some amount of time to be stored in order to make continuous flow water on turbine from for bay then let us assume the required storage volume is 20 seconds of turbine design flow according to the MHP design manual

So.$Volume_{storage} = \text{Q} * \text{stotege time}$ eq.4.11

$Volume_{storage} = \text{Q} * 20\text{se}$

$Volume_{storage} = 0.4\frac{m^3}{s} * 20\text{s} = 8m^3$

To store this water in the designed for bay tank we need additional depth of the tank so the depth of fore bay can be analyzed:-

$Depth_{storage} = D_{stor} = \frac{Volume_{storage}}{Area\ of\ tank}$ eq.12

$= \frac{8}{(2 * 6.2)} = 0.6m$

$Total\ depth\ of\ the\ forbaytank = H + D_{coll} + D_{sto}$............................eq.13

$= 0.5 + 0.5 + 0.6 = 1.6m$

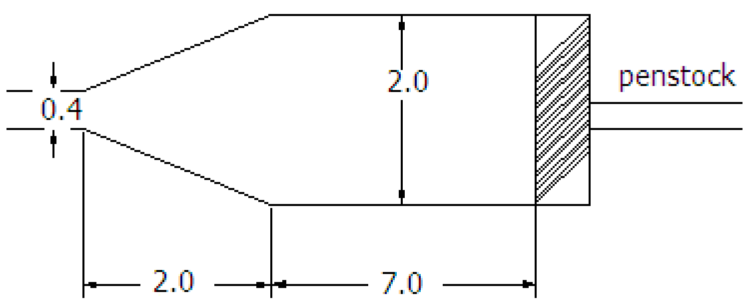


Fig. shows for bay of the site

3.7.1.5 Design of Penstock

The penstock is the pipe which conveys water under pressure to the turbine. If constitutes a major expense in the total micro- hydro budget. So it will be rise to minimize the cost as much as possible. The material we use for our penstock is mild steel, which is easily available & widely used.

In order to prevent sliding and movement of a steel penstock exposed on the ground surface, it has to be supported by anchor blocks at bends and dead ends, and by slide blocks at joints. Flanged joint is suitable for steel penstock and the thickness of flanges is often taken as twice the pipe thickness whenever the joint is embedded in slide blocks. The head losses through the penstock due to friction in the pipe, which should not be greater than 5% of the gross head, decrease dramatically with an increase in pipe diameter. Therefore, the design process has to be compromise between cost and performance.

To determine the dimensions of the penstock, first pipe sizes available on market are chosen and then head losses are computed.

4.1.5.1 Material selection for penstock

The material is selected according to the ground conditions, accessibility, weight, jointing system and cost. Accordingly, the material of the penstock is selected to be welded steel.

Table.9 comparison of different penstock materials.

Material	Young's modulus of elasticity, E $(N/m^2)*10^9$	Coefficient of linear expansion, a $(m/m\ ^oC)*10^{-6}$	Ultimate tensile strength N/m^2*10^6	Coefficient of roughness, n
Welded steel	206	12	400	0.012
Polyethylene	0.55	140	5	0.009
PVC	2.75	54	13	0.009
Ductile iron	78.5	10	140	0.014
Cast iron	16.7	11	340	0.015

In our case selected material welded steel by considering the loss in power 4% (Usually acceptable)\

3.7.1.5.Analysis of losses in penstock pipe

i.e. $h_1 = h_f = 4 * \frac{H}{100}$ ……………………………………………………eq.14

$h_1 = 0.6$

From Manning's equation; $\frac{h_f}{L} = 10.3\frac{n^2Q^2}{D^{5.333}}$--eq...15

$D = 2.69\left[\frac{n^2Q^2L}{H}\right]^{0.1875}$ …………………………………………………………………… eq.16

measured Length of Penstock $L = 25m$

Roughness coefficient $n = 0.012$

Available Head $H = 15$

$D = 0.379m$ by taking $D = 0.4m$

velocity $V = \frac{4*Q}{3.14*D^2} = 3.1 \approx 3\frac{m}{s}$ …………………………………………… eq.17

Using initial diameter check the total loss

1. Trash rack loss $ht \approx 0$

2)Inlet loss, for square entrance $k = 0.5$

$h_e = \frac{kv^2}{(2*g)} = \frac{0.5*3^2}{(2*9.81)} = 0.24m$ …………………………………………………… eq.18

3, Friction loss $h_f = 10.3L\frac{n^2Q^2}{D^{5.333}} = 0.032m$.………………………...………eq.19

Cross sectional area of the penstock $A = \frac{\pi}{4}d^2$………………………………eq.20

$$A = \frac{\pi}{4} * 0.4^2 = 0.125 = 12.56 * 10^{-2}m^2$$

The velocity of water through the penstock

$$V = \frac{Q}{A} = \frac{0.4}{(12.56 * 10^{-2}} = 3.1\frac{m}{s}$$

The type of flow through the penstock can be determined by calculating the Reynolds number (R_e).

R_e= (D*V)/υ ……………………………………………………………..eq.21

Where υ is the kinematic viscosity of the fluid, for water υ= $1*10^{-6}m^2/s$

R_e= $(0.36*1.375)/1*10^{-6}$

R_e=495000, the flow is a highly turbulent flow because the value is much greater than the critical Reynolds number (2000).

Head Losses in Penstock

Hydraulic losses in a penstock reduce the effective head in proportion to the length of the penstock *and* approximately as the square of the water velocity. Accurate determination of these losses is not possible, but estimates can be made on the basis of data obtained from pipe flow tests in laboratories and full-scale installations.

Net head, $H_n = H_{g1} - H_f$……………………………………………………………………………eq.22

The various head losses which occur between reservoir and turbine are as follows

Head loss due to friction (H_f)

Head losses in pipes because of friction vary considerably, depending upon velocity of flow, viscosity of the fluid, and condition of the inside surface of the pipe.

$H_f = f*(L/D)*(V^2/2*g)$ …………………………………..…………………eq.23

Where

L = Length of the penstock (20m)

D = Diameter of the penstock= (0.36m)

V = velocity of water through the penstock= (1.375m/s)

g = gravitational acceleration = ($9.81 m/s^2$)

f= Darcy friction factor, which depends on the material roughness, the penstock diameter and the type of flow.

$f = (1.254*n^2)/D^{1/3}$ ……………………………………………..………………………….eq.24

Where n= (Coefficient of roughness)

(Steel pipe: n = 0.012, plastic pipe: n = 0.011) material selected for the penstock is welded steel.

$f = (1.254*0.012^2)/0.36^{(1/3)}$

f= 0.025

Or else the friction factor 'f' can be found from moody chart. But the ratio of the roughness of the penstock material and the diameter of the penstock (ϵ/D) is required.

Where, Є= 0.6mm for welded steel

Є/D= (0.6/360) = 0.00166

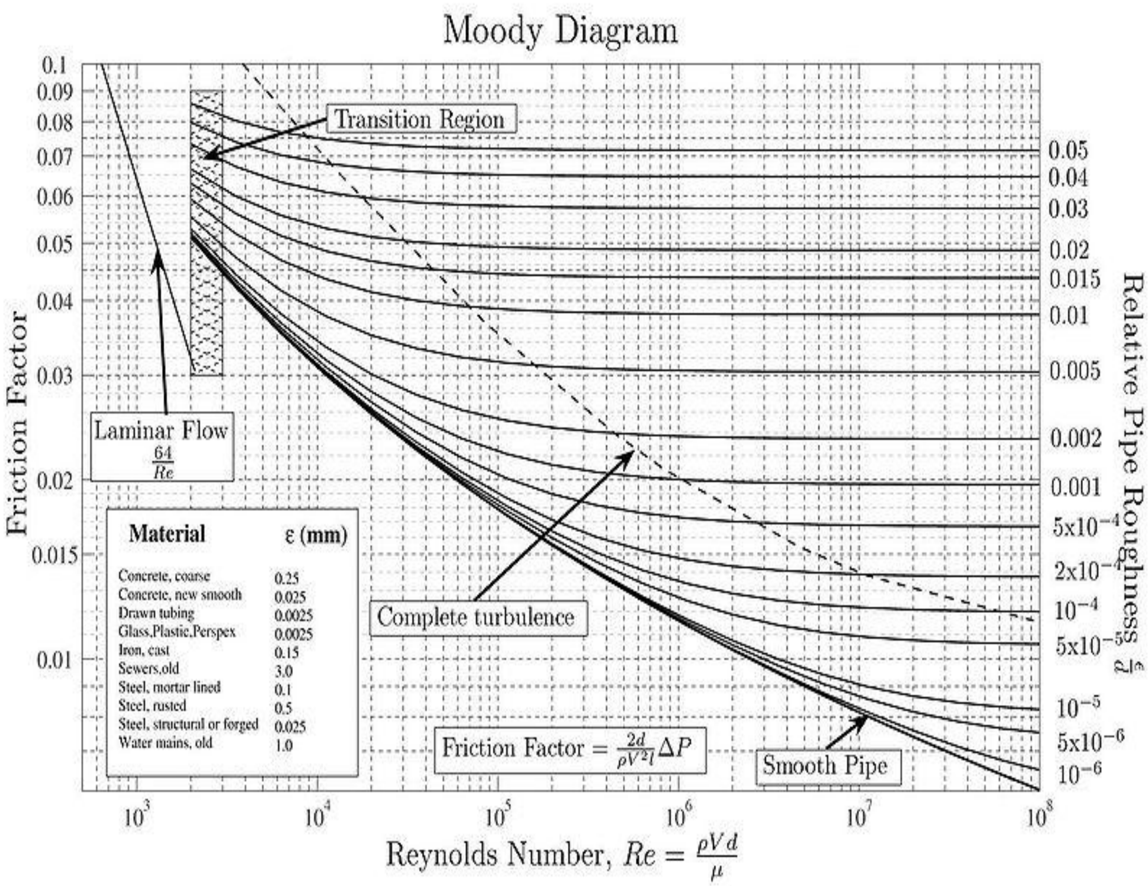


Figure.9.Moody Diagram from micro hydro power manual

From the moody chart the f is found to be 0.025 which is same as the above calculation.

The frictional loses in the penstock will be:

$H_f = 0.025*(20/0.36)/(1.375^2/2*9.81)$ $H_f = \underline{0.134m}$

Head loss due to turbulence Head loss due to turbulence includes inlet loss, valve loss and other loses.Inlet loss, h_i= k_e*(V^2/2*g)Where k_e is Coefficient on the form at the inlet (usually k_e= 0.5 in micro-hydro schemes with sharp inlet condition)

H_i= 0.5*(1.375^2/2*9.81) H_i= 0.0482m Valve Loss, H_v = k_v*(V^2/2*g)

Where, k_v Coefficient on the type of valve (k_v = 0.1 for butterfly valve)
H_v = 0.1* (1.375^2/2*9.81) H_v= 0.00964m

Other loses (H_o)

Bend loss and loss due to changes in cross-sectional area are considered other losses. However, these losses can be neglected in micro-hydro schemes. Usually, the person planning the micro-hydro scheme must take account of following margins as other losses.

H_0= 5%-10% of (H_f +H_i+H_v)

H_0 = 0.1*(0.134+0.0482+0.00964) = 0.0192m

The total head loss H_{loss} is the summation of all losses and it is found to be:

H_{loss} = (H_f + H_i + H_v + H_o)……………………………………………………………eq.25

= (0.134 + 0.0482 +0.00964 + 0.0192) = 0.21104m

But the value of the total head loss is too small. But in real experience the head loss is between 10%-20% of the total head. Taking 10% of the total head, the head loss becomes 1.2m.

The available net head H_n for developing power become:

H_{loss}= 10 % (12m) = 1.2m

H_n= 12m-1.2 = 10.8m

= 0.120m

Total loss hl = ht + he + hf …………………………….…….………………….eq.26

hl = 0.462m

Percentage p = 0.462m *100/15 = 3.08% of the total head

So since it is <4% then it is ok!

Then the net head H_{gross}- Total head loss =13.538=13.5m even the analytical loss value become based on the manual it recommend 90% the gross head to consider the net design head

Total head loss becomes 3.08% of the total head. Therefore use D = 0.379m = 37.9cm

To calculate the penstock diameter we can use the following empirical formula

Optimum diameter of Penstock formula

$D = L * Q^{0.38}$ …………………………….…………………………….eq.27

D - Internal diameter of pipe in mm

Q - Design flow in l/s

$D = 25 * (400)^{0.38}$

$D = 399mm = 400mm$

Therefore, pipe diameter of 400 mm (standard) with thickness of 3mm is selected for our case particular site. Sizing & installing an expansion joint

$X = \text{a}\,(\text{T hot} - \text{T cold})$ ……………………………………........eq.28

The lowest temperature in the site will be 10c in night and 300c during day.

So x = a (T hot - T cold) L $x = a(T_{hot} - T_{cold}$

$12 * 10^{-6}(29 - 1) * 25m = 0.084m = 84mm$

Where the length of our penstock is 25m length

$12 * 10^{-6}(29 - 1) * 25m = 0.084m = 84mm$

3.7.1.6 Hydraulic & structural design (wall thickness)

Ultimate tensile strength of steel S = 350 * 10^6

Young's modulus of elasticity E = 200 * 10^9kg/m^2

Minimum thickness of pipe (d in cm) = 10(d+50)/400

= 10(40+50)/400 = 2.25mm

Chose trial wall thickness t = 33mm

Pressure Wave velocity =

$$a = \frac{1400}{\sqrt{1+\left(\frac{2.1*10^9*d}{E*t}\right)}}$$ ……………………………………eq.27

Wave velocity $a = a = \frac{1400}{\sqrt{1+\left(\frac{2.1*10^9*0.379}{200*10^9*0.0033}\right)}}$

a =1400/rad(1+1.2)………………………………………..………eq.28

=1400/ (0.67) =942.6m/se

Velocity V = (4Q)/(3.14D^2) = 3.08m/s.

Even if v= 3.08m/se

We took v= 1.64m/se

H_{surge} = av/g

= (942.6*1.64m/s)/9.81

= 157.5m

Htotal = H_{surge} + H ……….…………………………………………………eq.30

= 157.5`m + 14m = 171.5m

Effective thickness for steel welded pipe t_{eff}= t/1.1 = 3.3/1.1 = 3mm

Safety factor = $SF = \frac{t_{eff} * S}{5 * H_{total} * 10^3 * d} \geq 3.5$ ………..……………………..eq.31

$$SF = \frac{0.003*350*10^6}{5*171.5*10^3*0.379}$$

Since the value of S.F 3.2< 3.5it is acceptable

So teff=3.mm

Hoop stress = (0.1 * Htotal *d)/(2*t) ≤ 1500 kgf/cm^2 (t & d in mm)

= (0.1*171.5*379)/ (2*3.0) = 1083.3< 1500

Then it is acceptable, so the wall thickness is = 3mm

3.7.2 Electro Mechanical works

RunnerDiameter

$$D = \frac{40 * \sqrt{H}}{N}$$ ……………………………………………………………eq.5.1

Where D is runner diameter (mm) C is the velocity constant for the nozzle, which is defined as the ratio of the actual average velocity achieved to that predicted from Bernoulli's equation. This constant cannot be determined accurately before doing the experiment for the turbine to be manufactured. This value signifies the smoothness or roughness of the nozzle. The higher the C the smoother the nozzle is and vice versa. Typically this constant ranges from 0.95 (rougher nozzle) to 0.99 (smoother nozzle)

K is an experimental coefficient which relates the jet thickness to the diameter of the runner. According to [33], this value ranges from 0.075 to 0.1. The value of this constant ultimately determines the number of blades required. For example a value of K=0.075 corresponds to blade number of 21 while that value of K=0.1 corresponds to 16 blades. For calculation purpose, as the author did, the value of K to be taken is the mean of the value of Therefore, the mean value is K=0.087 corresponding to which the number of blades is 18.

3.7.2.1 Design of the Rotor

The choice of the blade inlet and outlet angles is the important part of the design. They have to be chosen so that the jet of water transfers useful work to the rotor in both passes through the blades. Throughout this analysis, angles are measured from tangents to the circles and are positive in the direction of rotation. Also we assume at design point the incident angle is zero and the deviation angle is very small so that the design will not be affected if we assume the deviation to be zero.

From the velocity triangle, by simple geometry we have for all cases $\alpha 2=\alpha_3$; this is true for all shaft speeds and flow inlet velocities

$$D = \frac{40 * \sqrt{H}}{N}$$

$$= \frac{40 * 13.5^{1/2}}{463.7} = \frac{146.9}{463.7} = 0.316m$$

Therefore, the adapted diameter of the runner is to be 320mm.

Thickness of jet entrance is right angle to tangential of runner. This also enables us to calculate the optimum thickness of the jet, which is the same as nozzle width.

$t_{jet} = 0.1 * D_1 - 0.2 *$

$D_1 = 316mm$

Then $t_j = (0.1 * 316mm + 0.2 * 316)$/2=0.0474

$t_{jet} = 0.0474mm$

Again to calculate the length of the cross flow turbine

- Whereas the length of the rotor can be calculate using the formula

$L_{runner} = \frac{Q}{t_{jet}*\sqrt{28g\,H_{net}}} = \frac{0.4}{0.771}$=0.518

blade spacing ca be calculate as S_1=KD_1

Butcoefficient k= 0.087

$s_1 = 0.087 * 0.316$=0.027492 =27.49mm

Blade thickness t= $\frac{S_1}{\sin B1} = \frac{27.49}{\sin(30)} = \frac{27.49}{0.5} = 54.98m$m

Number of blades n= $\frac{\pi D_1}{t} = \frac{3.14*316}{54.98mm} = \frac{992.24}{54.98} = 18$ 5.1.1 Curvature of the blade Jet thickness

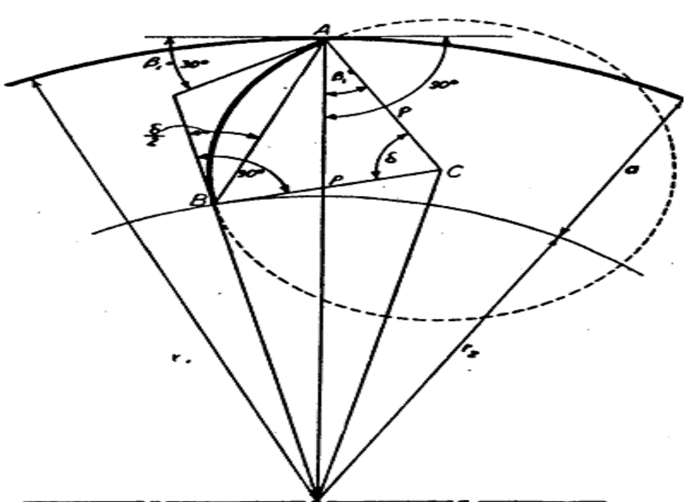


Fig-14 Curvature of the blade Jet thickness

The curve of the blade can be chosen from a circle whose center lies at the intersection of two perpendiculars, one to the direction of relative velocity W1 at point A and the other to the tangent to the inner periphery intersecting at point B in the figure-14

$(OB)^2 + (BC)^2 = (AO)^2 + (AC) - 2(AO)(AC)\cos\beta$ Where AO= r1 OB= r2 AC= BC= ρ

$\rho = [(r_1)^2 - (r_2)^2]/2*r1\cos\beta1$From the previous calculations

$\rho = 0.326r1$ $\rho = (0.326*0.5*D1$

$\rho = 48.4mm$

3.7.2.2 Central angle of the blade

Again from the above figure we can find the central bled angle

From the figure triangle co relation

$r1/r2 = \sin(180 - (1/2\delta))/\sin(90-(1/2\delta)+\beta1)$

$= \sin(1/2\delta)/\cos(1/2\delta)+\beta1)$ $\beta1 = 30$

$\tan(1/2\delta) = \cos\beta1/(\sin\beta1 + r2/r1)$

$\delta = 73.1$

3.7.2.3. Number of blades

We can find the number of blades for our turbine using the following relations t =пD1/n   n= пD1/t

n= (3.14*297mm)/51.5mm   = 18

For locally made turbine, jet thickness is taken between $0.1D_1$ to $0.2D_2$. Jet thickness S_o=0.1*d2to 0.2*d2 Even if in my design pre condition the turbine outer diameter is 297 mm and inner radius of rotor is **198 mm during design I take d1=300mm d2=199mm**

Where, So = jet thickness

S_o = (0.1*0.3) to (0.2*0.3) So

= 0.03 + 0.06=0.09/2 = 50mm

3.7.2.4 **Chord length across blade (L)**

$$L = 2\rho_c \sin\frac{\delta}{2}$$

$$L = 2*4.2*\sin(\frac{65}{2}) = 4.5cm$$

3.7.3. Nozzle profile

The only curve, in which the feature of forming a constant angle between its tangent and the line to its origin is inherent, is the logarithmic spiral.

- **The logarithmic spiral is expressed by the formula**

$r_ø=e^{\tan\alpha_1 [rad]}$ $R_ø = r_ø . R_1$ Where: R_1 = the outer radius of the runner

α	degre	tan(α)	rad	tan(α)*(rad)	$(ro)e^{\tan(\alpha)*(rad)}$	R1	Ro=ro*R1
16	0	0.300632	0	0	1	0.316	0.316

16	**1**	**0.300632**	**0.017453**	**0.005247**	**1.005261**	**0.316**	**0.301578**
16	**2**	**0.300632**	**0.034907**	**0.010494**	**1.010549**	**0.316**	**0.303165**
16	**5**	**0.300632**	**0.087266**	**0.026235**	**1.026582**	**0.316**	**0.307975**
16	**10**	**0.300632**	**0.174533**	**0.05247**	**1.053872**	**0.316**	**0.316161**
16	**15**	**0.300632**	**0.261799**	**0.078705**	**1.081886**	**0.316**	**0.324566**
16	**20**	**0.300632**	**0.349066**	**0.10494**	**1.110645**	**0.316**	**0.333194**
16	**30**	**0.300632**	**0.523599**	**0.157411**	**1.170477**	**0.316**	**0.351143**
16	**50**	**0.300632**	**0.872665**	**0.262351**	**1.299985**	**0.316**	**0.389996**
16	**70**	**0.300632**	**1.22173**	**0.367292**	**1.443822**	**0.316**	**0.433147**
16	**90**	**0.300632**	**1.570796**	**0.472232**	**1.603574**	**0.316**	**0.481072**
16	**120**	**0.300632**	**2.094395**	**0.629643**	**1.876948**	**0.316**	**0.563084**
16	**130**	**0.300632**	**2.268928**	**0.682113**	**1.978062**	**0.316**	**0.593419**
16	**150**	**0.300632**	**2.617994**	**0.787053**	**2.196925**	**0.316**	**0.659077**
16	**180**	**0.300632**	**3.141593**	**0.944464**	**2.571451**	**0.316**	**0.771435**

α_1 = water inlet angle at the first sta $R_ø$= the radius which gives the required nozzle profile

3.7.4 Radial Rim Width (a)

From the empirical formula;

, $\quad Radia\ Rim\ width\ (a) = O.1\ _{D_1}$

Where, D_1 = the outside diameter of the wheel (D_1=0.316m)

Therefore; $(a) = O.17\ _{D_1} = 0.17 * 0.316m = 0.0537m$

$a = 53m$

$Also\ a = r_1 - r_2 = (D_2 - D_2)/2$

Where, D_2 = inner diameter of the wheel

$D_2 = D_1 - 2 * a$

$D_2 = 0.316 - 2 * 0.053 = 0.21$

then $D_2\ = 210mm$

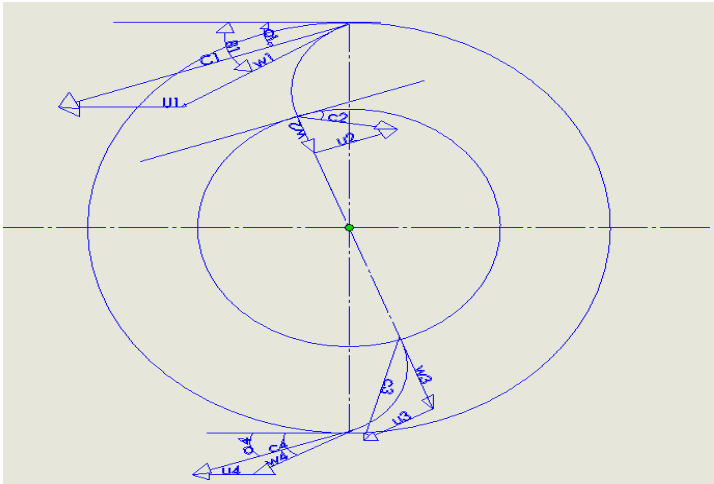


Figure 10.Velocity diagram of rotor.

Where

U= peripheral velocity of the runner

W= relative velocity

C=absolute velocity

α= jet angle and

β=blade angle

Assumptions:

The inter stage angle of the blades is taken equal to 90^o (i.e. the outlet angle of the first stage or pass and the inlet angle of the second stage, β_2 and β_3).

Concept behind this Assumption

Assuming zero deviation angle for the flow leaving the blades in the first pass; therefore, the flow relative velocity angle will be equal to the blade outlet angle. Normally the values of deviation angle are of the order 2^o to 8^o. Therefore, the optimum value for the blade outlet angle is between 91^o to 94^o. Obviously taking the blade angle equal to 90^o would not cause considerable effect on the performance.

Accordingly:

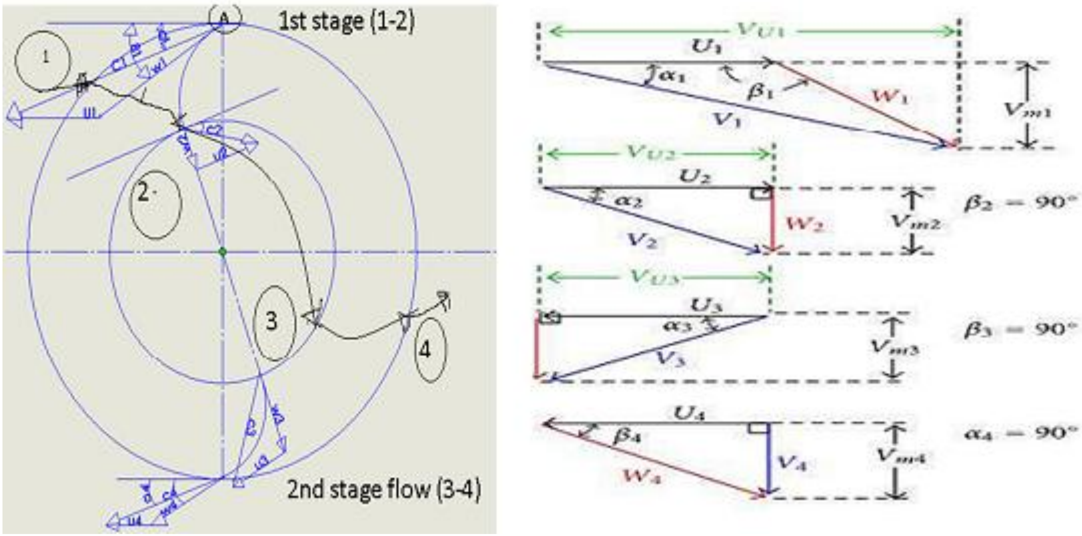


Fig.11 velocity triangle to find the water flow angle

Assumptions

$\alpha_1 = 16^o$,

If U1 = $C_1 \cos\alpha_1/2$

Then $\tan\beta_1 = 2\tan\alpha_1$

$\beta_1 = \tan^{-1}(2\tan\alpha_1) = \tan^{-1}(2\tan16^0)$

Therefore $\beta_1 = 30^o$

$\beta_2 = \beta_3 = 90^o$

$U_2 = U_3$

$U_1 = U_4$

3.7.3.1*Peripheral velocity of the runner at inlet of first stage (U_1)*

$$U_1 = \frac{3.14 * D_1 N}{60}$$

$$U_1 = \frac{3.14 * 0.316 * 463.7}{60}$$

$$U_1 = 7.668\ \frac{m}{s}$$

Path of jet through turbine:

Assuming that the center of the jet enters the runner at point A In the above velocity diagram at an angle of α_1, with the tangent to the periphery.

Assuming all the potential energy is transformed to kinetic energy at the inlet of the runner and a nozzle coefficient of 0.98.

The absolute velocity of the water before entering would be:

$$C_1 = C_d * (2 * g * h)^{\frac{1}{2}}$$

$$C_1 = 0.98 * (2 * 9.81 * 13.5)^{\frac{1}{2}} = 15.9 \frac{m}{s}$$

Where, C_1 = Absolute velocity of water

C_d = Coefficient dependent upon the nozzle

The relative velocity of water at entrance W_1 can be found from the velocity triangle as:

$W_1 \sin \beta_1 = C_1 \sin\alpha_1$

$W_1 = 14*(\sin 16^0/\sin 30^0)$

W_1 = <u>7.67m/s</u>

The Absolute velocity of the water before entering would be

$\mathbf{V_1 = C_d*(2gH)^{1/2}}$

Where, V_1 = Absolute velocity of water

C_d = Coefficient dependent upon the nozzle

$V_1 = 0.98*(2*9.81*13.5)^{1/2}$

V1 = 15.9 m

The peripheral velocity at the exit of first stage (U_2)

$U_2 = (\pi *D_2*N)/60 U_2 = (\pi*0.210*463.7)/60$

U_2= <u>5.09m/s</u>

By Considering 20% loss in the velocity of water while it passes over the blade surface

Due to friction on the runner blades

$W_2=0.8*W_1$

$=0.8*7.668$m/s

W_2=<u>6.13m/s</u>

But as we can see from the velocity diagram $\beta_2=\beta_3=90°$, so that the probability of formation of shock on the runner will be decreased.

Hence:

$C_2^2=U_2^2+ W_2^2$

$C_2 = (5.09^2 + 6.13^2)^{1/2}$

$C_2 = \underline{8.16 m/s}$

$\cos\alpha_2 = (U_2/C_2)$

$\alpha_2 = \cos^{-1}(U_2/C_2) = \cos^{-1}(5.184/8.16)$

$\alpha_2 = \underline{50.56}°$

Considering the height (h) due to the fall inside the cross section, calculate the increase in absolute velocity at inlet of second stage (C_3).

$C_3 = [C_2^2 + (2*g*h)]^{½}$ but h is equal to the inside runner diameter, D_2.

Hence, $C_3 = [8.16^2 + (2*9.81*0.21)]^{1/2}$

$C_3 = \underline{8.4 m/s}$

Since, $\beta_2 = \beta_3$ and $U_2 = U_3$,

so simply we can calculate the relative velocity at inlet of the second stage.

$\cos\alpha_3 = (U_3/C_3)$

$\alpha_3 = \cos^{-1}(5.184/8.4)$

$\alpha_3 = \underline{51.9°}$

From the velocity triangle, $C_3^2 = W_3^2 + U_3^2$

The relative velocity at the inlet of the second stage

$W_3 = (C_3^2 - U_3^2)^{1/2}$

$= (8.4^2 - 5.184^2)^{1/2}$

$W_3 = \underline{6.61 m/s}$

Considering equal percentage loss in friction in similar case to the first stage

$W_4 = 0.8*W_3$

$= 0.8*6.61$

$W_4 = \underline{5.288 m/s}$

From the velocity diagram we also have the information $U_1 = U_4 = 7.854$m/s and $\beta_1 = \beta_4 = 30^o$, applying sine rule on the velocity triangle:

$C_4/\sin(180-\beta_4) = W_4/\sin\alpha_4$

But $C_4^2 = U_4^2 + W_4^2 - (2*U_4*W_4*\cos\beta_4)$

$= (7.854^2 + 5.288^2) - (2*7.854*5.288*\cos 30°)$ $C_4 = \underline{4.21 m/s}$Since $\alpha_4 = (W_4/C_4)*\sin 30°$ $\alpha_4 = \sin^{-1}[(5.288/4.21)*\sin 30°]$$\alpha_4 = \underline{38.9°}$

***3.7.5 TurbineEfficiency**:-*

Typical efficiency ranges of turbines are tabulated in the above table Turbines are chosen or are sometimes tailor-made according to site conditions. Selecting the right turbine is one of the most important parts of designing a micro-hydropower The turbine selection is done using the turbine selection chart for net head of 13.5m and 0.4m3/s discharge measured at bita woreda yina kebele shoshi micro hydropower hydro site.

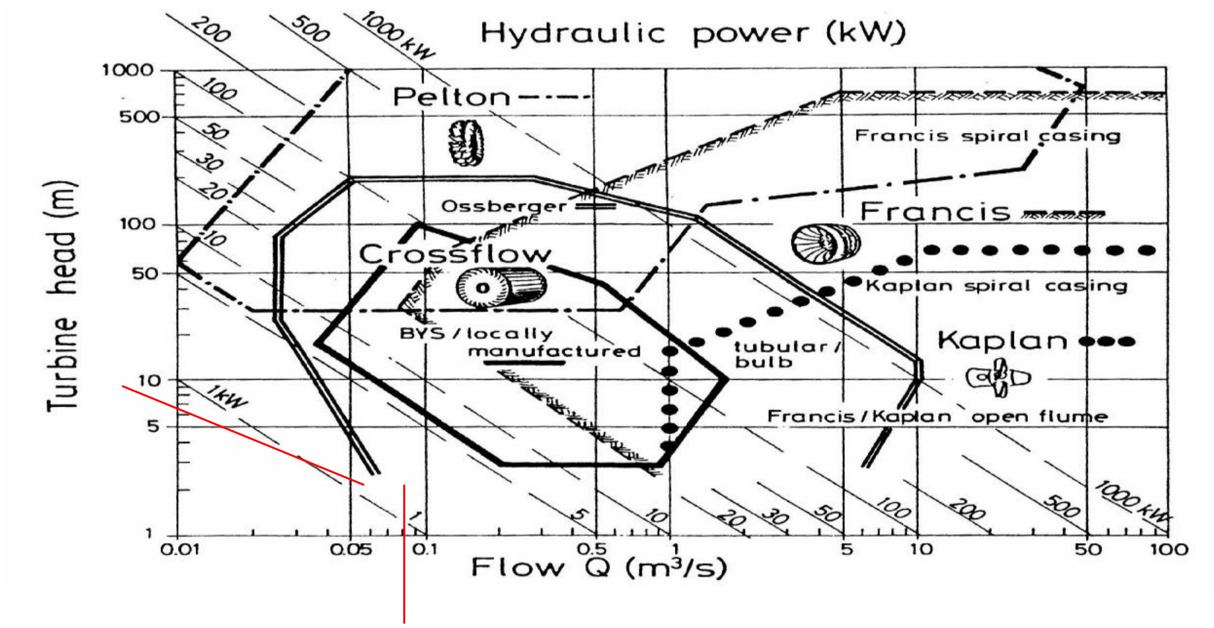


Fig .12. Turbine selection chart from micro hydro power manual by adam Harvey

Therefore from the above chart we can see that cross flow turbine suits best for the site.To calculate the rpm of the cross flow turbine I used two types of formula

To calculate the cross flow turbine I used the R.W.Abbett's formula

$N = \frac{1700}{\sqrt{H}}$ --eq.5.7

$= \frac{1700}{\sqrt{13.3}} = \frac{1700}{3.67}$

$= 463.2$

Remandan Sadek and Mohamed Afaty siebel's formula

$N = \frac{1750}{H^{0.51}}$ --eq.5.8

$N = \frac{1750}{13.5^{0.51}} = \frac{1750}{3.77} = 464.2$

$by\ taking\ the\ average N = 463.7$

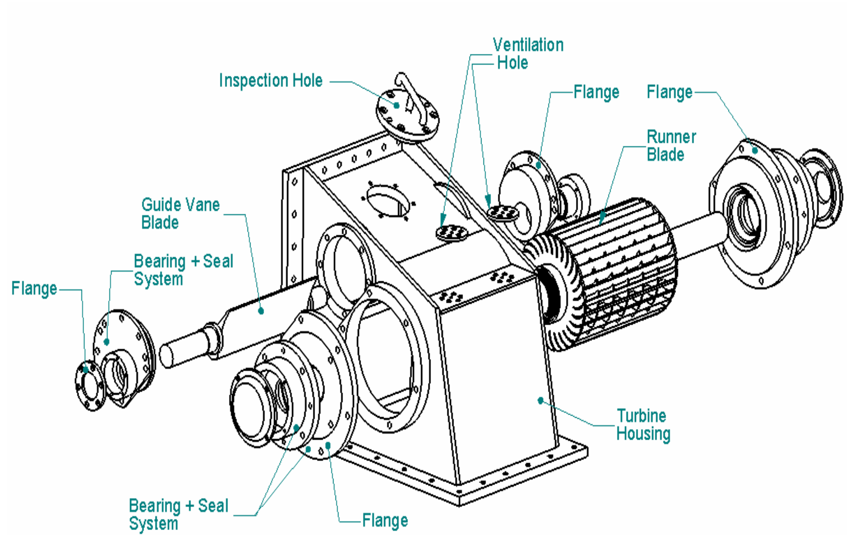


Fig .13 General assembly of T12 cross flow turbine

Advantages of cross flow turbine:

- Simple design
- Good standardization runner width can be adapted to design flow so it is easy to build the turbine precisely for the specified site needs
- Manufacturing without the need for sophisticated manufacturing facilities.
- Relative low production costs compared with other turbine designs

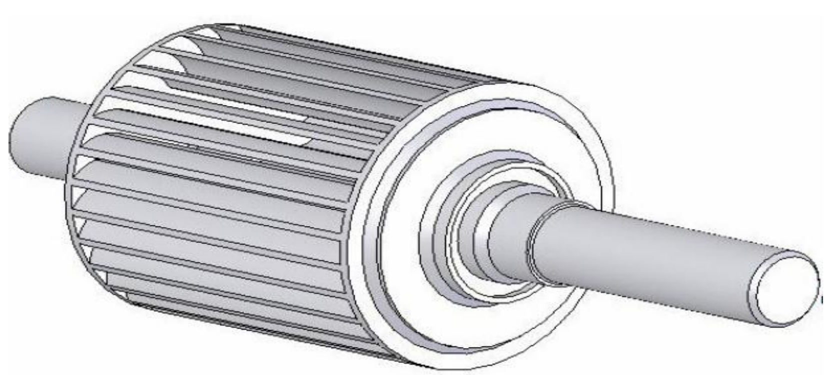


Fig 14. T12 Cross flow runner

3.7.6 Sizing of T12 cross flow turbine

Calculated result

- Design head 13.5m
- Design discharge 400 l/sec
- Diameter of the runner 0.316m
- Length of the runner 1.44m
- Cross flow rpm 463.7
- Electrical power output = 34.4kw

3.7.7 Specific speed

A very comprehensive and commonly used definition is the specific speed n_q. This specific speed n_q is simply the speed of an imaginary turbine, with such a size, that at 1m head a flow of $1m^3/s$ occurs (at the best efficiency point)

One option to determine the application range of a specific turbine design is the specific speed. The specific speed of the turbine is computed as follows:

$$N_S = \frac{N * P^{1/2}}{(13.5^{1.25}} \quad \text{---eq5.8}$$

$$= \frac{463.7 * \sqrt{34.4}}{(13.5)^{1.25}} = \frac{463.7 * 5.8}{(13.5)^{1.25}} = \frac{2689}{25.9}$$

$$= 103.8 = 104$$

3.8. ELECTIRIC SYSTEM

In general electric system for micro hydro power application comprises of:

1. Generator

2. Control system (including protection, metering, interconnection)

3. Power transmission system (load controller, cables, and wooden poles)

4. Service connection and house wiring

3.8.1 GENERATOR

The generator is an electrical machine coupled to the turbine shaft. The mechanical energy produced by the turbine is changed in to electrical energy by the generator.

The sizes of the generator vary depending on their rating & on their shaft arrangements (either vertical or horizontal)Generators convert the mechanical (rotational) energy produced by the turbine to electrical energy; this is the heart of any hydro electrical power system.

The principle of generator operation is quite simple: when a coil of wire is moved past a magnetic field, a voltage is induced in the wire.

Alternating current (AC) generators are also referred to as alternators. They generate varying voltages, which alternate above and below the zero voltage point. It is this process that produces AC electricity.

There are two types of generators:-

3.8.1.1 Synchronous and Asynchronous.

Synchronous generators are standard in electrical power generation and are used in most power plants. Asynchronous generators are more commonly known as induction generators. Both of these generators are available in three-phase or single-phase systems. Systemcapacity, type of load and length of the transmission/distribution network dictate whether a single- or three-phase generator should be used. Induction generators are generally appropriate for smaller systems. They have the advantage of being rugged and cheaper than synchronous generators.

The induction generator is a standard three-phase induction motor, wired to operate as a generator. Capacitors are used for excitation and are popular for smaller systems that generate less than 10 to 15 kW. All generators must be driven at a constant speed to generate steady power at the frequency of 60 Hz

Types of Generator

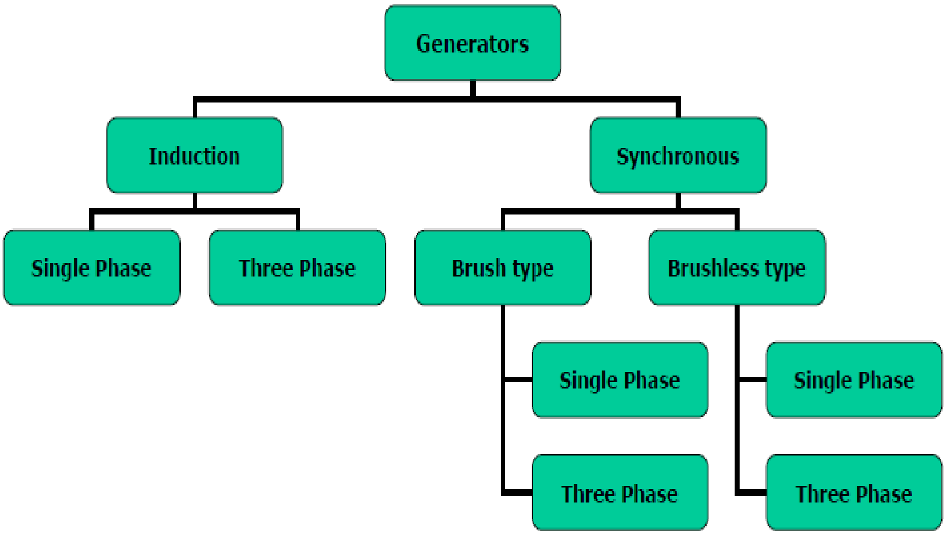


Fig.15. Types of generators for MHPP

3.8.1.1 Synchronous generator

Widely used in most power generation (diesel gas and water. Etc.

Efficiency and technical characteristic is relatively good (>85%), since it developed specifically for power generation

ʘ widely available on almost every size from 3kw-100mw

ʘ the cost is relatively cheap 100-120 USD/KW for European brand

ʘ commonly already equipped with automatic voltage regulator (AVR) and without brush any more brush less

ʘ capable in handling motor start up current for certain time

ʘ electronic load controller (elc) is use to maintain the power and frequency and it cannot with stand the over speed for certain time especially industrial type

ʘ The turbine is coupled to a synchronous generator is used (n_g=1500 rpm) with a flat belt transmission.

Generator speed n_g =1500 rpm

Gearing ratio i = 1500 rpm / 463.7 rpm = 3.2

3.8.1.2 Generator KVA

$GeneratorKVA = \frac{InstalledCapacityinkw}{A*B*C}$ Plus ~30% for safety factor, with the reasons:

Possible output bigger then calculated bigger size better insulation, generator will run cooler thus longer lifetime can be expectedPossible expansion of the load in the futureMinimize momentary voltage reduction when connecting motor (start-up)When using ELC the generator will always run at full load.

Table.10 Factors affecting generator size from micro hydro power design manual

Factor affecting the generator size

	Max. ambient temperature in °C	20	25	30	35	40	45	50	55
A	*Temperature Factor*	*1.10*	*1.08*	*1.06*	*1.03*	*1.00*	*0.96*	*0.92*	*0.88*
	Altitude	1000	1500	2000	2500	3000	3500	4000	4500
B	*Altitude Factor*	*1.00*	*0.96*	*0.93*	*0.90*	*0.86*	*0.83*	*0.80*	*0.77*
C	ELC Correction Factor								0.83*
D	Power Factor	When load is light bulbs only							1.0
		When load includes tube light and other inductive loads							0.8

For maximum ambient temp of 30°C, altitude 2618 m: A= 1.06, B= 0.942, C=0.83, D=0.8.

Hence Generator KVA= 34.4KW/ (0.942*0.8*1.03)

= 13.15 KVA

30% safety factor

Generator KVA = 1.3* 13.15 KVA

= 17.1 KVA

$$rotationalspeed = \frac{120f}{p} rpm$$

f =Frequency = 50HZ P =Number of poles = 4

Rotational speed = 1500 rpm

3.8.2 Driving Systems

The driving system consists

3.8.2.1 V belts and pulleys

3.8.2.2 Shafts

3.8.2.3 Bearing selection

ʘ Belt Drive

The belts are used to transmit power from one shaft to another by means of pulleys which rotate at the same or different speeds. The amount of power to be transmitted depends on the following factors.

ʘVelocity of belt

ʘTension under which the belt is placed on the pulleys

ʘ the arc of contact between the belt and the smaller pulley

ʘ the condition under which the belt is used

For our case, we choose a v belt due to the following advantages over the flat belts.

ʘ the drive gives compactness due to small distance between centers of pulleys.

ʘ the drive is positive, because the slip between the belt and the pulley groove is negligible.

ʘ it provides longer life.

ʘ can be easily installed and removed.

ʘ High velocity ratio may be obtained.

ʘ it can be operated in a vertical, horizontal or inclined direction.

ʘ for the design the necessary information's needed are

ʘ Power to be transmitted P = 34.4kw

ʘ Rotational speed of the runner N_2 = 463.7rpm.

ʘ Rotational speed of the generator N_1= 1500rpm

ʘ in our design V flat drives are selected.

3.8.3 Power Transmission Device

Power is transmitted from one shaft to the other by means of belts, chains and gears. The belts and ropes are flexible members which are used where distance between the two shafts is large. The chains also have flexibility but they are preferred for intermediate distances. The gears are used when the shafts are very close with each other.

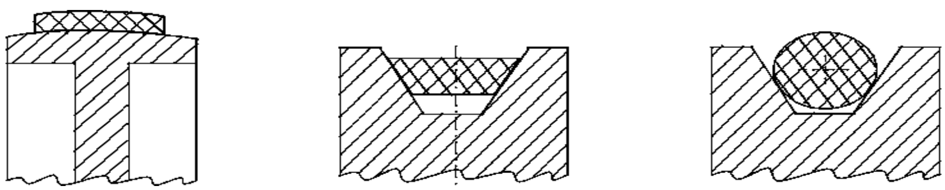
This type of drive is also called positive drive because there is no slip. If the distance is slightly larger, chain drive can be used for making it a positive drive. Belts and ropes transmit power due to the friction between the belt or rope and the pulley. There is a possibility of slip and creep and that is why, this drive is not a positive drive.

Mechanical power can be similarly transmitted across large distances in the form of rotational motion. Rotating shafts transfer motion from point to point along their axis of motion. There are two possible solutions for power transmission from the turbine shaft to the generator shaft. These are belts & pulleys.

Belt Selection

In case of belts, friction between the belt and pulley is used to transmit power. In practice, there is always some amount of slip between belt and pulleys, therefore, exact velocity ratio cannot be obtained. That is why; belt drive is not a positive drive. Therefore, the belt drive is used where exact velocity ratio is not required.

The following types of belts and pulleys shown in figure 3.1 are most commonly used for purpose power transmission activity.



(a). Flat Belt and Pulley

(b) V-belt and Pulley c) Circular Belt or Rope Pulley

Figure 16 Types of Belts and Pulley

The flat belt is rectangular in cross-section. The pulley for this belt is slightly crowned to prevent slip of the belt to one side. It utilizes the friction between the flat surface of the belt and pulley.

The V-belt is trapezoidal in section. It utilizes the force of friction between the inclined sides of the belt and pulley. They are preferred when distance is comparative shorter. Several V-belts can also be used together if power transmitted is more. For my case, I selected V-belt or Wedge belts (types of vee belt that is usually used for micro-hydropower application) that are marked with SPB based on cross-sectional area of the belts. Under this the following parameters will be estimated.

- Design Power = Power to be transmitted X Factors
- Selecting Minimum Pulley Diameter
- Find larger pulley diameter
- Calculate approximate center distance
- Obtain Rated Power/Belt
- Calculate the number of belts
- Calculate Belt Length
- Belt speed and width
- Calculate Belt tension

Turbine shaft speed are, N=500rpm

Generator speed, N_1=1500rpm. Therefore,

Speed ratio is 3:1

Turbine power = 34.4kw

Torque developed by generator

$$= \frac{p*60}{2\pi N} = \frac{9.72*1000*60}{2\pi*1500} = 64.43Nm$$

Design power for belts = $p_{out} * factor = 9.72kw * 1.18 * 1.2 = 13.8kw$ [Where, Service Factor = 1.18 & Duty Factor = 1.2].

Based on this result, Belt type was selected: SPB Wedge Belt [From Fenner Belt Selection Envelopes]

Pulley selection

With corresponding design power calculated, from standard table minimum pulley diameter would be selected. Thus, 140mm diameter is selected as minimum pulley diameters. Selecting the minimum recommended pulley, using the Design Power and the faster shaft speed. This is a guide to the minimum pulley pitch diameter capable of transmitting the design power at the given speed, without generating excessive bearing loads.[From Fenner Wedge Belt Catalogue]

Larger pulley diameter become = $3 * 140mm = 420mm$ since there is no pulley specified with this mark, the nearest standard pulley dimension of 450mm is taken as larger one. Speed ratio when computed using new large pulley dimension, 3.21:1. So, corresponding generator rpm will be N_1 = 3.21*500 = 1600rpm but it is safe. Approximate center distance between two pulleys can be calculated using the following formula, $c = D_L + D_S$= 450mm+140mm=590mm

Length of the Belt

For any type of the belt drive it is always desirable to know the length of belt required. It will be required in the selection of the belt. The length can be determined by the geometric considerations. However, actual length is slightly shorter than the theoretically determined value. Open belt drive is mostly suitable for micro hydropower scheme.

The open belt drive is shown in Let O_1 and O_2 be the pulley centers and *AB* and *CD* be the common tangents on the circles representing the two pulleys. The total length of the belt '*L*' is given by: *L* = *AB* + Arc *BHD* + *DC* + Arc *CGA*

Let *r* be the radius of the smaller pulley,

R be the radius of the larger pulley,

C be the center distance between the pulleys, and

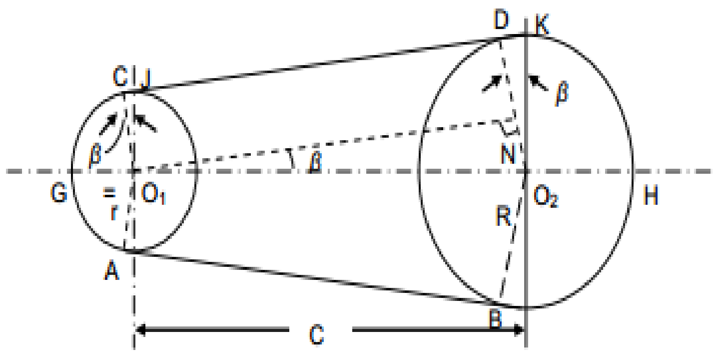


Figure 3.9 : Open Belt Drive

Fig open penstock drive

Draw *O*1 *N* parallel to *CD* to meet *O*2 *D* at *N*.

By geometry, < *O*2 *O*1, *N* = <*C O*1 *J* = < *D O*2 *K*=*β*

Arc *BHD* = (*π*+ 2β) *R*,

Arc *CGA* = (*π*+ 2β) *r*

AB = *CD* = *O*1 *N* = *O*1 *O*2 cosβ = *C* cos

$$L = (\pi + 2\beta)R + (\pi - 2\beta)r + 2c\{1 - \frac{1}{2}sin^2\beta\}$$

For small value of $\beta; \beta = (\frac{R-r}{c})$ when it is substituted in equation below, the approximate belt length becomes

$$L = \pi(R + r) + \frac{(R-r)^2}{c} + 2c\{1 - \frac{1}{2}\frac{(R-r)^2}{c^2}$$

Where R = 225mm and r = 70mm Belt length, $L = \pi(R + r) + \frac{(R-r)^2}{c} + 2c\{1 - \frac{1}{2}\frac{(R-r)^2}{c^2} = 1707.67mm$ but this length is not available on standard table. Therefore, the corrected belt length becomes 1956mm with 1.05 correction factors.

These powers require correcting for belt length and arc of contact correction factor and should be used in conjunction with the appropriate Service Factor. Basic power per belt from power rating table diameter 140mm at 1500rpm.Corresoping rating power will be read from standard table.Rated Power per Belt = $7.09\frac{kw}{belt}$[From Fenner Wedge Belt Catalogue]Speed ratio power increment is calculated by interpolation and it becomes$1.21\frac{kw}{belt}$. And then corrected rated power per belt =$(7.09 + 1.21) * 1.05 = 9\frac{kw}{belt}$. Now it is possible to calculate number of belts.

$Number\ of\ belts\ (n) = \frac{Design\ power}{power\ per\ belt} = \frac{14.33}{9} = 1.6 \cong 2$, so that two belts are required.

Belt Tension (T_o) = 32Pn where, P is the force required to deflect the belt 16mm of the entire belt span. The formula and value of P = 65N is taken from the Fenner Wedge Belt Catalogue. Therefore, belt tension of small pulley can be calculated as follow:

$$T_o = 32 * 65 * 2N = 4{,}160N$$

Belt Speed 140mm diameter of pulley at 1500rpm gives

Belt speed = $\frac{ND_s\pi}{60} = 11.02\frac{m}{s}$

Belt width = $\frac{P_{outMF}}{p*60}$ =110mm

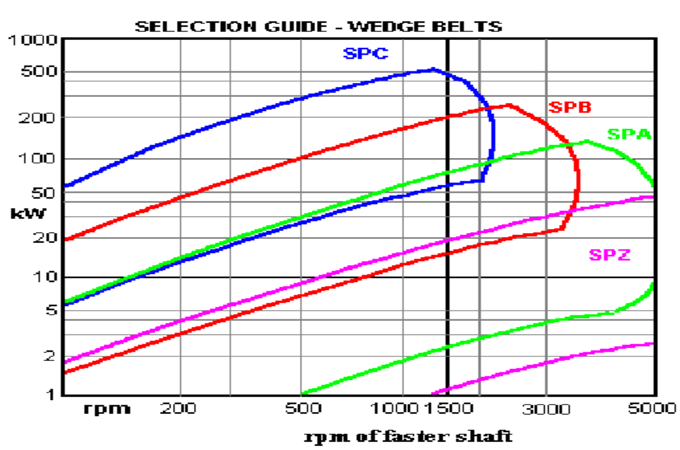


Figure 17 Belt Selection Envelopes (Fenner Wedge Belt Catalogue

Bearings

All shafts run in bearings. The function of a bearing is to allow a shaft to rotate freely with a low coefficient of friction and at the same time hold the shaft in the correct position against any forces imposed on the shaft. The two main families of bearings are sliding bearings and rolling element bearings.

Sliding Bearings

Sliding bearings require correct lubrication and regular maintenance. They are not usually used for micro-hydro schemes.

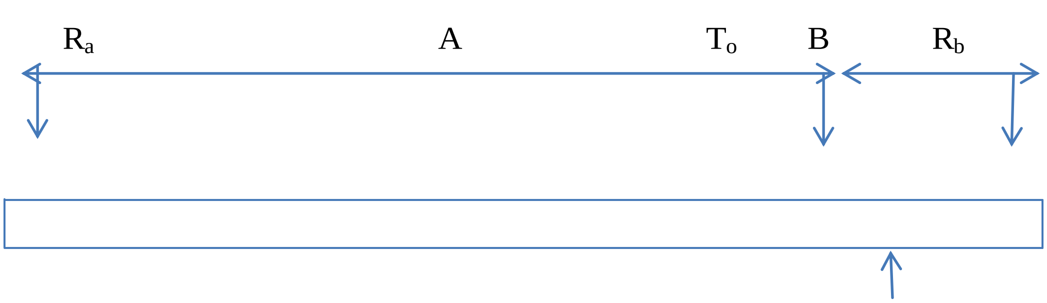
Rolling Element Bearings

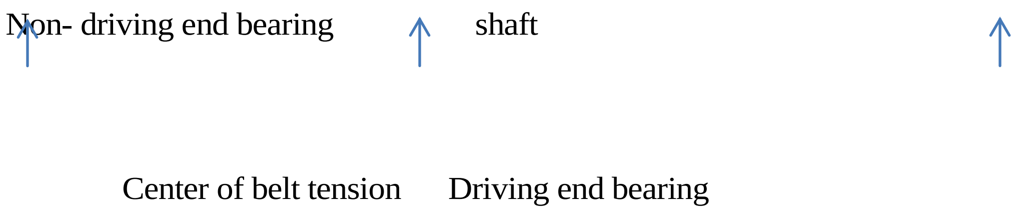
The characteristics of common types of bearings are shown in Table Rolling element bearings include the very common ball bearings as well as other types. Correctly installed, lubricated and protected from water and dirt they will run trouble free for thousands of hours without the need for any attention.

Detailed information from SKF about deep groove ball bearings (the usual common ball bearings) is given in Fig 5.1. It should be noted that ball bearings only are available with seals and shields incorporated into the bearing. The use of shields and seals is recommended in micro-hydro applications, as dust and dirt should be prevented from entering the bearing. When plain or spherical roller bearings are required it is necessary to fit external seals into the bearing housing.

Bearing Load Calculations

Calculation of the loads applied to bearings is necessary in order to choose the correct type and size of bearings. These calculations will be demonstrated as follow.



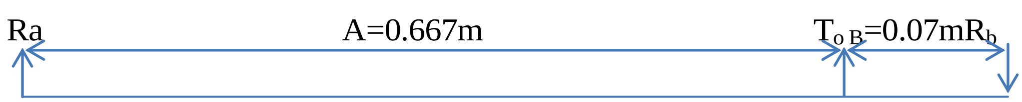


Calculate the loads applied to the bearings of a generator with a C234/244A frame and driven by wedge belts. The total shaft length is 806.5 mm and the part of the shaft where the pulley is fixed is 140 mm.

We can then assume that

A = 806.5 — 140.0 = 0.6665 mm = 0.667m and that if the pulley is fixed centrally on the shaft extension, then B = $\frac{140mm}{2} = 70mm = 0.07m.$

For the sake of clarity we are not including the self-weight of the generator rotor, which can be taken as force acting halfway between Ra and R_b. The generator total weight is assumed as 536 kg; assume half this weight is the rotor, giving a force of 2.6 kN. This should be taken into account in a full calculation of bearing loads. The simplest way is to add $\frac{2.6}{2}$kN to each of the two bearing radial loads. Notice that if you do this in the following calculation, the effect of rotor weight is small.



Force diagram

Belt tension force, $T_o = 4{,}160N$

Taking moments about R_a:

$0.737R_b = 0.667 \times 4.160kN$

$R_b = 3.76kN$

Resolving vertically: $T_o + R_a - R_b = 0$

$R_a = R_b - T_o$ = 3.76 kN-$4.16kN$= -0.4kN the negative sign shown that the reacting force is in opposite way. Thus, the radial load on the 'drive end' bearing is 3.76 kN and on the 'non-drive end' is 0.4kN.Let us consider the life of the drive end bearing R_b. I took specific bearing that is recommend on certain references, this bearing is a deep-groove ball bearing type **6211-2RS1** made by SKF, and the shaft diameter in the bearing is 50mm. The outer diameter of this bearing is 100mm and width is 25mm.

The bearing life is expressed as

$$L_{10h} L_{10h} = \frac{1000000}{60n} * \frac{C^q}{P^q}$$

where L10h= bearing life in hours n= rotational speed in rpm

C= Dynamic load rating in newton p= Equivalent dynamic load

q = Exponent for life equation. For ball bearings q = 3 and for roller bearings q = 3.3.

Equivalent dynamic load (P) is calculated as $P = X F_r + Y F_a$

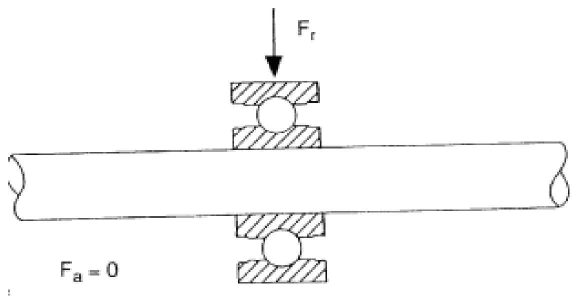
Where F_r = Radial load = 3.76 kN and F_a = axial load X and Y are factors. The value of each factors are displayed in Table below.

Table Calculation factors X and Y for deep groove ball bearings

F_a/C_0	e	X	Y
0.025	0.22	0.56	2.0
0.04	0.24	0.56	1.8
0.07	0.27	0.56	1.6
0.13	0.31	0.56	1.4
0.25	0.37	0.56	1.2
0.50	0.44	0.56	1.0

The above values for X and Y apply when $F_a / F_r > e$. When $F_a / F_r \leq e$ use X = 1 and Y = 0.

These factors take account of the applied forces F_a and F_r, the relationship between them, and the relationship of F_a to the static capacity of the bearing.



In our case, $F_a = 0$ so F_a/C_0 is 0

Also, $F_a/F_r = 0$ and consequently less than any value of e quoted. Therefore, X = 1 and Y = 0. Where there is no axial load, as in this case,

$P = X*F_r = 1 * 3.76kN = 3.76kN$

Dynamic load rating (C) may be found from bearing manufacturers' catalogue gives the relevant information for a 6211-2RS1 bearing, where: C = 43.0kN and rotational speed (n) for the 50Hz alternator is 1500 rpm.

Therefore, bearing life become

$$L_{10h} = \frac{1000000}{60n} * \frac{C^q}{P^q} \quad = \frac{1000000}{60 * 1500} * \frac{43}{3.76}^3 = 16{,}617\ hours$$

Or bearing life, = $\frac{16{,}617}{24 * 30} = 23\ months\ = 1.95\ years$

Shaft Design

The shaft design has been based on the maximum bending moment criterion and returns a conservative result. Following is the procedure followed (Adam H., 1999):

- Calculation of Bearing Loads
- Calculation of Maximum Bending Moment
- Calculation of shaft diameter

When the shaft is subjected to combined twisting and bending moment, then the shaft must be must be designed on the basis of the two moments simultaneously. Various theories have been suggested to account for the elastic failure of the material when they are subjected to various types of combined loads/stresses. The following two theories are important

- Maximum normal stress theory or Rankine's theory used for brittle Material.
- Maximum shear stress theory or Guest's theory used for ductile materials. For my case the second theory is more preferred one for calculation of shaft diameter.

Design calculation

In shaft design; the maximum torque transmitted to the circular shaft is calculated from below expression, $T_e = \frac{P_{out}}{\omega}$ .But angular speed of the turbine shaft when it is calculated becomes as follows$\omega = \frac{2\pi * 500}{60} = 52.36\frac{rad}{s}$.Therefore, torque developed by runner shaft, $Torque = \frac{10120w}{52.36\ rad/s}$ = 193.28Nm.With assuming of allowable shear stress as the maximum shear stress and calculating the equivalent torque, the diameter of shaft can be determined.

Forces exerted on shaft

The forces exerted on the shaft are the jet force exerted or imposed by the water and the tensional force exerted by the rotation of the runner blades.

The jet force exerted is given by;

$$F_j = \frac{Torque}{r_o}$$

$$F_j = \frac{193.28Nm}{0.1311m} = 1.470kN$$

The arrangement of the shaft and the blades in the rotor are the connecting struts are situated parallel in horizontal position from left to right side way. The support bearings are set at a location leveled just at 192mm far from center of runner and 392mm far in right side of the runner.

Assuming the jet force imposed is uniformly distributed along the length of the runner the point of concentrated force application can be taken at the mid span of the shaft bearing support which is 192mm as shown in the figure below.

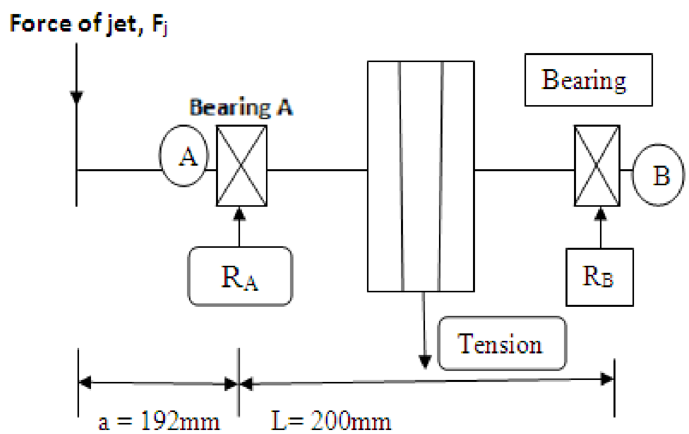


Figure - Runner Shaft Arrangement

Taking moment at point B to estimate reaction force on bearings:

$$R_A * 0.2 - T * 0.1 - F_j * 0.392 = 0$$

R_A = 4969.6N= 4.97kN

$$R_A + R_B = F_j$$

$$R_B = F_j - R_A = 1.47kN - 4.970kN = -3.5kN, it\ is\ acting\ opposite\ direction\ with\ R_A$$

Bending moment is going to be calculated as follow. Bending moment at any point is the sum of the forces to the left of that point times distance from left to the point. Therefore,

Moment at runner = 0.

Moment at A = - (1.47kN)*0.192m = -0.282kNm

Moment at belt center = - (1.47kN*0.292) + (4.970kw*0.1)

= -0.429kNm+0.497kNm = 0.068kNm

Moment at B = - (4.16kn*0.1) + (4.97kn*0.2)-(1.47kn*0.392) = 0 Therefore, maximum bending moment is at point A= 282Nm.

Shaft material is C_{40} steel with yield strength of $\sigma_y = 300\frac{N}{mm^2}$& Ultimate strength

$$,\sigma_{ult} = 580\frac{N}{mm^2}.\ t_p = 0.3\sigma y \text{and } t_p = 0.18\sigma_{ult}$$

Diameter of shaft can be determined can be determined from ASME formula

$$d = [\frac{5.1}{t_p}\{(C_m M)^2 + (C_t T)^2\}^{0.5}]^{0.33}$$

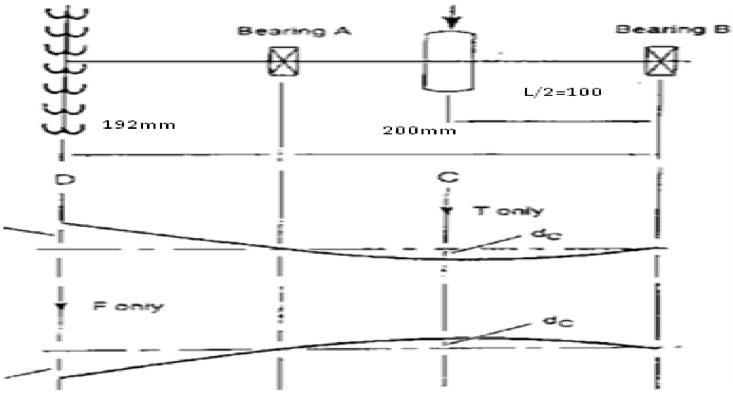
The equivalent twisting moment is given by shock (C_m) and fatigue factors (**C_t**) for bending twisting are 1.5 & 1 respectively.

Therefore, d = 50.47mm= 50mm

Shaft Deflection

It is normal to calculate the size of shafts from strength considerations. It is advisable to check that such a shaft will deflect only within allowable limits. The maximum allowable deflection for machine shafts may be taken as 0.0005 times the distance between bearings. No position on the shaft must deflect more than that amount irrespective of whether the position is between or outside the bearing centers. Shaft deflections are calculated by the method used for beams. Most engineering handbooks contain diagrams and formulae for common arrangements.

A common way of calculating deflections for arrangements where there is more than one load is to calculate deflections separately for each load in turn and then to add the deflections algebraically. Care must be taken to use + and - signs do correctly to signify the direction of the deflection.



Shaft deflection

E is the modulus of elasticity of the shaft material (E) = 0.196 x 10^{12} N/m^2 and I is the moment of inertia of the shaft and is given by $, I = \frac{\pi D^4}{64}$.Formulae for calculating the deflections are:

d_{CT} = -Tl^3/48EI d_{DT} = +Tal^2/16EI

d_{CF} = +Fal^2/16EI d_{DF} = -Fal^2 (l+a)/3EI

To determine the deflection (d) at the turbine runner for the arrangement shown in Fig 7.7

Refer to symbol given above.

Deflection (d) caused by Force of jet only:

$$d_{DF} = -\frac{Fa^2(l+a)}{3EI} = -\frac{1470*(0.192)^2*(.2+0.192)}{3EI} = -\frac{21.24}{3EI}$$

Deflection (d) caused by belt tension only: $d_{DT} = +\frac{Tal^2}{16EI}$

$$= +\frac{4,160*0.192*0.2^2}{16EI} = +\frac{31.95}{16EI}$$

Deflection resulting from both Force and Tension T:

$$\frac{31.95}{16EI} - \frac{21.24}{3EI} = \frac{95.85-339.84}{48EI} = -\frac{243.99}{48EI}$$

E = 0.196 x 10^{12} N/m^2 and $I = \frac{\pi D^4}{64} = \frac{\pi * 0.05^4}{64} = 3.068e^{-7} * m^4$.

Deflection (d) $= -\frac{243.99}{48 * 0.196 * 10^{12} * 3.068 * 10^{-7}}$

$= -8.4510^{-5}\, m$ = -0.0845mm the minus sign indicates direction only

This deflection is acceptable as allowable deflection is 0.0005 x 200 = 0.10mm.

Therefore, it is safe for shaft to operate at required load.

Estimation of power demand

2 lighting with energy saving lamps @11W = 22W

Television/Radio = 60W

Total energy consumption per house hold = 82W

Running hour of the plant,

Total running hours, per day 15 hour from Monday to Friday & 24 Saturday and Sunday 105 hours per week.

- Total running hours, will be 492 hour per month.
- Energy Consumption 82w*492h=40.34 KWh/hh/month

Assuming 20 birr energy cost tariff from consumer energy cost become per kwh=0.61 birr

- Gross tariff to be collected 9950 birr per month

Expenses expected

- Expenses for plant manager 500birr
- for operator 500 birr
- total expenses 1000birr per month
- Nate saving per months 9950-1000 =**8950 ETB**

Annual saving =**107,400 ETB**

3.9 .COST EVALUATION AND ECONOMIC ANALYSIS

3.9.1 General

Hydroelectric plants generally are quite competitive and economical when compared to the Conventional fossil fuel based power plants. However, the small hydro, especially the mini and Micro hydro, installed in remote hilly regions are somewhat costlier and are competitive to Conventional power only when allowances for external costs associated with fossil fuels and Nuclear power etc are considered. The geographical and geological features along withthe effective head, available flow, equipment (turbines, generators etc.) and civil engineering works determine the capital required for any small hydro power project.

For estimating whether a particular MHP scheme is financially feasible, several financial tools and techniques can be used. The simple payback period method is the easiest to calculate though a more rigorous test for financial viability is to check the net present value (NPV) and the internal rate of return (IRR). NPV and IRR take into consideration the several factors and are designed to incorporate the time value of money.

The ratio of the total investment to the power installed or the ratio of the total investment to the annual energy produced for a project is also useful while considering investment decisions between a numbers of projects. This is a sort of an initial assessment decision and does not take into account the profitability of a given scheme.

Simple Payback method

The payback method determines the number of years required for the invested capital to be offset by resulting benefits. The number of years required for the investment to be recovered is called as

$$\text{Payback period.} = \frac{Investment\ cost}{net\ anual\ revenue}$$

The method usually does not capture the opportunity cost of capital. The opportunity cost of capital is the return from the same capital from an alternative investment activity the MHP. Investment costs are usually defined as initial costs (civil works, electrical and hydro mechanical equipment) and benefits are the resulting net yearly revenues expected from selling the electricity produced, after deducting the operation and maintenance costs, at constant value money.

Usually, if the payback period exceeds 7 years then the small hydro project is to be considered to be not profitable. However, the payback method does not compare the selection from different technical solutions for the same installation, or choosing among several projects.

In fact it does not consider cash flows beyond the payback period and thus does not measure the efficacy of the investment over its entire life. Under the payback method of analysis, projects with shorter payback periods rank higher than those with longer paybacks. For the investor, when using this method it is advisable to accept projects that recover the investment and if there is a choice, select the project, which pays back earliest. This method is simple to use but it is attractive if liquidity is an issue but does not explicitly allow for the “time value of money” for investors

Return on Investment method

the return on investment (ROI) calculates average annual benefits, net of yearly costs, such as depreciation, as a percentage of the original book value of the investment. Then it can be calculate as

$$A\textbf{Return on Investment} = \frac{net\ anual\ revenue - depreciation}{Investment\ cost} * 100$$

Using ROI can provide a quick estimate of the project’s net profits, and can provide a basis for comparing several different projects. Under this method of analysis, returns for the project’s entire useful life are considered (unlike the payback period method, which considers only the period that it takes to recover the original investment). However, the ROI method uses income data rather than cash flow and it completely ignores the time value of money. To resolve this problem, the net present value of the project, as well as its internal rate of return should be considered.

Economic analysis of hydropower project concern measuring the benefit from the development and the cost expended. In the context of hydropower planning, benefits are the service produced by the development and costs are the goods used in constructing and maintaining the development. An economic analysis is necessary to determine whether the project is worth building or to determine the economic size of the development or the components of the development

3.9.2 Bill of Quantities and Cost estimation

The economic analysis of the project studies is dependent on orderly and accurate cost estimation. The type of study, whether a reconnaissance study, a feasibility study or a final design study, will tend to dictate the precision with which cost estimates have been made.

The total cost of the project is been estimated as follows depending on the bill of quantities and their corresponding unit rates. This tabular description of cost should be analyzed from each structure parametrically.

Table .11 Bill of quantity (BOQ) for a specific site yina village micro hydro plant

s.n	w. description	unit	unit rate	Amount	Column1
1	**Weir and Intake**				
1.1	**concrete work**				
1.1.1	Concrete for the base of weir	m^3	7.2	4300	30960
1.1.2	Concrete for canal intake gate	m^3	0.58	4300	2494
1.1.3	Reinforced concrete for pillars	m3	3.1	4300	13330
1.1.4	Steel reinforcement for pillars	kg	150.49	3500	526715
1.1.5	Form work	m2	43.2	1200	51840
	Total summary				**625339**
1.2	Masonry work				
1.2.1	For Retaining wall	m3	5.16	795	4102.2
1.2.2	For weir body	m3	11.52	795	9158.4
1.3	plastering				
1.3.1	Cement plaster for face of weir and wing wall	m2	42.5	30	1275
1.3.2	Pointing on the back of wing	m2	6.6	30	198

	wall				
	Total summary				**14733.6**
2	**Canal work & for bay**				
2.1	Concrete work				
2.1.1	Reinforced concrete for topping of for bay	m3	2.48	4000	9920
2.2	**Masonry work**				
2.2.1	Masonry for canal foundation	m3	29.42	795	23388.9
2.2.2	Masonry for canal wall	m3	35.48	795	28206.6
2.2.3	Masonry for bay foundation	m3	7.72	795	6137.4
2.2.4	Masonry for bay wall	m3	13.14	795	10446.3
2.3	Floor lining				
2.3.1	Plastering on canal & pillars	m2	104.11	30	3123.3
2.3.2	Pointing on for bay	m2	28.8	30	864
	Total to summary				**82086.5**
3	**Power house & penstock line**				
3.1	Concrete work				
3.1.1	Reinforced concrete for beams columns & tail race	m3	4.1	3510	14391
3.1.2	Concrete for anchor 7slide block	m3	1	3510	3510
3.1.3	Reinforcement bar	kg	462.28	35	16179.8
3.2	**Masonry work**				
3.2.1	Masonry for anchor & slide blocks	m3	5	750	3750
3.2.2	Masonry for power house foundation	m3	6.4	750	4800
3.2.3	Masonry for tail race	m3	11.85	750	8887.5
3.3	plastering				
3.3.1	Plastering internal & external walls	m2	20.4	30	612

3.3.2	Plastering for anchor blocks	m2	14.9	30	447
3.4	**Block works**				
3.4.1	Hollow cement blocks 20x20x40 cm	m2	42.76	230	9834.8
3.5	**Roofing**				
3.5.1	Roof trusses	pcs	5	185	925
3.5.2	G-28 corrugated iron sheet	m2	23.76	220.06	5228.6256
3.5.3	Chip wood Ceiling	m2	12	120	1440
3.5.4	5x7 cm wanza purlin	pcs	6	185	1110
3.6	Metal work				
3.6.1	Metal windows	pcs	2	1100	2200
3.6.2	Metal door	pcs	1	1550	1550
	Total carried to summary				**74865.7256**
4	Transports				
4.1	Truck loads to the site	trips	3	2250	6750
4.2	Fixing flush & canal intake gates	pcs	3	420	1260
4.3	Transport & fixing penstocks	pcs	12	150	1800
	Total carried to summary				**9810**
5	**other work**				
5.1	Hard rock excavation	m3	26.67	300	8001
5.2	Mobilizing of construction site	lump sum			15000
5.3	site clearing	Lump sum			5000
5.4	Diversion channel	Lump sum			10000
	Total to summary				**38001**
6	Additional works				
6.1	Retaining wall				
6.1.1	Trench excavation	m3	84	70	5880
6.1.2	Masonry work for the wall	m3	87.8	795	69801
6.1.3	concrete work for the base	m3	5.6	3200	17920
6.1.4	Plastering work	m2	112	30	3360

	Total to summary				**96961**
	project total Cost				**316457.826**
	Vat				**79007.25**
	Total project cost with 15 % Vat				**395,465.076**

Electro mechanical part

S.No	Electro Mechanical Machine	Unit	Q.ty	Unit P	T. Price
7	**electro mechanical machine**				
7.1	T15 cross flow turbine 34.4 kw,500 rpm	pcs	1	4500	10,500
	13.5 net head and 400l/s				0
7.2	synchronous generator of 35kw,1500rpm,50hz	pcs	1	10000	10000
7.3	simple belt derive that cam convert 500rpm to 1500rpm	pcs	1	500	500
					0
8	grid installation				0
8.1	electric cables	meter	1700	25	42500
8.2	poles(optional)	pcs	60	15	900
9	metal work				0
9.1	window with frame 1x1 m out of steel	pcs	1	1300	1300
9.2	penstock 340mm	lump sum	5	5600	28000
9.3	entrance door 1x2 m with lock	pcs	1	1550	1550
9.4	trash rack made by 40x40x4mm angle iron	pcs	1	14358	14358
9.5	canal intake gate	pcs	1	8043	8043
9.6	flush gate near the for bay	pcs	1	5200	5200
	sub total				**122351**

	VAT	15%			**18352.65**
	TOTAL E.MECHANICAL COST				**140,703.6**

Total project cost withg vat = 395,465.076 +134378.65 = 536,168.6ETB

3.9.*3 Annual cost and cost recovery factor*

This is the sum of the money invested in a project (including its interest during Construction) before its completion. Since both benefits and costs comes about different times, it is necessary to evaluate the benefit and costs in equivalent monetary terms. The equivalent annual cost calculated from the total cost of the projects will be

$$CRF = \left[\frac{i(1+i)^{\ n}}{i(1+i)^{n}-1}\right]$$ ……………………………………………………………………..eq.8.3.1

Where i= annual interest rate =10% (assumed)

n= estimated life of the project = 20 years

$$CRF = \left[\frac{0.1(1+0.1)^{\ 20}}{0.1(1+0.1)^{20}-1}\right]$$ =0.1175

Annual recovery cost= CRF ×total project cost=0.1175×536,168.6

= 62,999.8

Operation and maintenance cost = 2% of the total project cost

= 0.02*536,168.6= 10,723.3

BY adding contingency of 5%, the total annual cost becomes:

= 0.05*10,723.3+10,723.3

=11,259.4

3.9.4 Benefit of the project

From the installed capacity, total power expected to generate 334.4kW. Currently EELPA sales a 1KWhr of electric energy by 0.388 Birr. So, the energy produced by the project is given by:

34.4kw =34400w

Elpa sales 1kwh by 0.388birr=0.4birr

E=34.4×365day×24hour×0.4birr=**120537.6 birr**

Benefit cost ratio

Therefore, benefit to cost ratio will be,

$$\frac{B}{C} = \frac{120{,}537.6}{62{,}999.8+10{,}723.3+11{,}259.4} = \frac{120{,}537.6}{84{,}982.5} = 1.418$$

Since B/c ratio is greater than one the project is economically feasible

4. Result and discussion

Based on Technical Assessment

Site is said to be technically attractive & promising if more than two of the following factors exists;

- Slope of water conveyance system or ratio of water head to canal length is 10% or better.
- Head of water is more than 30m.
- Firm capacity (power potential at dry season) is more than demands.
- Low degree of difficulties or risks
- Synergies with other projects or installations e.g. Irrigation, water supply
- large part of the equipments can be manufactured & maintained locally by the community

So, based on the above requirement the potential sites are summarizes as follows

Table.17 shows the results on identification of potential sites

No	Site Name	Distance From bonga (Km)	Distance from gride line	Discharge(m^3/s)	Net Head(m)	Power output (KW)	Status
1	Shosha/yina	110	20km	0.4	13.5	34.4	Feasible
2	Woshi	58	12	0.132	9	7.5	feasible
3	hamani	35	7	0.097	5.4	3.3	Not feasible
4	Geshi	45	11	0.24	7.2	11.8	feasible
5	Didifa	96	10	0.29	11.2	22.7	feasible
6	kico	79	12	0.173	9	12.8	feasible
7	Guma	45	10	0.23	14	14.5	feasible

Result from specific site system design of shoshi river yina kebele

Turbines parameters	dimensions
Length of penstock	25m
Diameter of penstock(internal)	o.4m
Diameter of penstock (outside)	0.5
Outer diameter of runner	316mm
Inner diameter of the runner	210mm
Blade inlet angle	16^0
Shaft diameter	55mm
Smaller pulley diameter	200mm
Larger pulley diameter	600mm
Number of blade	18

5. CONCLUSIONS, AND RECOMMENDATION

5.1 CONCLUSION

To be successful for any sustainable development three major factors need to be in an optimum harmony: Energy, Economy and Ecology .Energy access and consumption level is an indicator for the wellbeing and development level of a Household [26] in this regard it is possible to forecast the willing of each house hold to participate/ to have share both in cash and in kind to the project that will be construct in nearby feature.

The socio-economic study indicated that social and economic situation of the HHs in the study area is well suited for community oriented development practice with more than 70% of the HHs having an annual income of more than $ 350/yr. Moreover, they currently have an energy expense of $18/year-$36/year for lighting only

Finally because of this research 6 potential sites are identified, so from this 6 potential site we can generate power 103.7kw and the total energy **2488.8wh** /day means 2488800wh considering per house hold consumption 82w From this potential sites 30,351 house hold or 182,107 people would be electrified this shows that the power that could be generated from each power plant site is more than enough of the load to be supplied and even it can supply for an increase in demand of at least 50% of today's demand. Except one sites at Hamani sites which not feasible for MHP, the remaining are taken to be a hydro-only system. The result for the design of both electro mechanical and civil work components design analyzed based on the data found from field survey and others from literatures.

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Appendixes

Community load rating and scheduling

		Resident house					h.post				elementary school					
		refrigerator	tv	rad/tape	street ligh	room lum	frezer	tv	street ligh	room lum	room lump	street light	TV	radio tape	refrigerator	total
	1	1.1		5.52	1.6	3.8	0.22	0.33	0.32	0.11	0.66	0.8	0.22	0.03	0.22	14.93
	2	1.1	2.75	5.52			0.22	0.33		0.11			0.22	0.03	0.22	10.5
	3	1.1	2.75	5.52			0.22	0.33		0.11			0.22	0.03	0.22	10.5
	4	1.1	2.75	5.52			0.22	0.33		0.11			0.22	0.03	0.22	10.5
morning	5	1.1	2.75	5.52			0.22	0.33		0.11			0.22	0.03	0.22	10.5
	6	1.1	2.75	5.52			0.22	0.33		0.11			0.22	0.03	0.22	10.5
	7	1.1	2.75	5.52			0.22	0.33		0.11			0.22	0.03	0.22	10.5
	8	1.1	2.75	5.52			0.22	0.33		0.11			0.22		0.22	10.47
	9	1.1	2.75	5.52			0.22	0.33		0.11			0.22		0.22	10.47
afternoon	10	1.1	2.75	5.52			0.22	0.33		0.11			0.22		0.22	10.47
	11	1.1	2.75	5.52			0.22	0.33		0.11			0.22		0.22	10.47
	12	1.1	2.75	5.52	1.6	3.8	0.22	0.33	0.32	0.11	0.66	0.8	0.22		0.22	17.65
	1	1.1	2.75	5.52	1.6	3.8	0.22	0.33	0.32	0.11	0.66	0.8	0.22	0.03	0.22	17.68

Night	**2**	**1.1**	**2.75**	**5.52**	**1.6**	**3.8**	**0.22**	**0.33**	**0.32**	**0.11**	**0.66**	**0.8**	**0.22**	**0.03**	**0.22**	**17.68**
	3	**1.1**		**5.52**	**1.6**	**3.8**	**0.22**	**0.33**	**0.32**	**0.11**	**0.66**	**0.8**			**0.22**	**14.68**
	4	**1.1**		**5.52**	**1.6**	**3.8**	**0.22**	**0.33**	**0.32**	**0.11**	**0.66**	**0.8**			**0.22**	**14.68**
	5	**1.1**		**5.52**	**1.6**	**3.8**	**0.22**	**0.33**	**0.32**	**0.11**	**0.66**	**0.8**			**0.22**	**14.68**
	6	**1.1**		**5.52**	**1.6**	**3.8**	**0.22**	**0.33**	**0.32**	**0.11**	**0.66**	**0.8**			**0.22**	**14.68**
	7	**1.1**			**1.6**	**3.8**	**0.22**		**0.32**			**0.8**			**0.22**	**8.06**
	8	**1.1**			**1.6**		**0.22**		**0.32**			**0.8**			**0.22**	**4.26**
	9	**1.1**			**1.6**		**0.22**		**0.32**			**0.8**			**0.22**	**4.26**
	10	**1.1**			**1.6**		**0.22**		**0.32**			**0.8**			**0.22**	**4.26**
	11	**1.1**			**1.6**		**0.22**		**0.32**			**0.8**			**0.22**	**4.26**
	12	**1.1**			**1.6**		**0.22**		**0.32**			**0.8**			**0.22**	**4.26**

Questioner Used For Data Collection MHP potential assessment research

- **Data Collection (Interview)**

1. Site Specification

1.1. Name of Wareda -----------------------------------

1.2. Distance from Jimma Town (Km) --------------------------

1.3. Name of Kebele in the Wareda ---------------------------------

1.3.1. Distance from Wareda Town (Km) ----------------------------

1.3.2.Road accessibility

Accesses for Vehicle

1.4. Number of households in the Kebele ------------------------------

1.5. Dominant energy sources used in the Kebele consumption rate

Benzene ___________

Fire wood _________

Agricultural residue _

Other (please specify) --

2. Catchment Area

2.1. Name of the river --------------------------------

2.2 upstream irrigation project……………………………………………

2.3. Average annual income (birr) ---------------------------------

2.4. Average number of rooms in a house -------------------------------

Type of households

No	parameters	Households (HHS)			
I		Man		woman	
1	Family size	male	female	Male	female
2	Children < 5yrs old				
3	Children 5<>15 yrs old				
4	Youngsters >15yrs old				
5	Adults				
II	Elementary school				
1	Students in junior and secondary school				
2	Students in high school				

3.Devices/Appliance Used

3.1. Currently used appliance (from direct survey in the catchment)

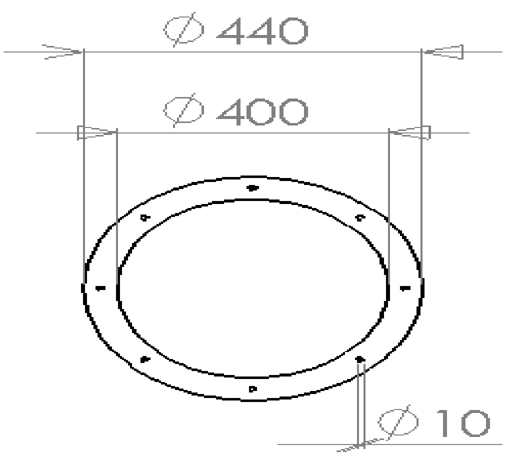
- **Radio Power by dry cell battery -----------------------------/catchment**
- **Solar powered radios -------------------------------------/catchment**
- **Other (specify) --**

3.2. Future forecast for appliance usage (through discussion with Kebele Admin & HHs

- **Radio --------------------------------------/catchment**
- **TV ---/ catchment**
- **Lump -------------------------------average/HHs**

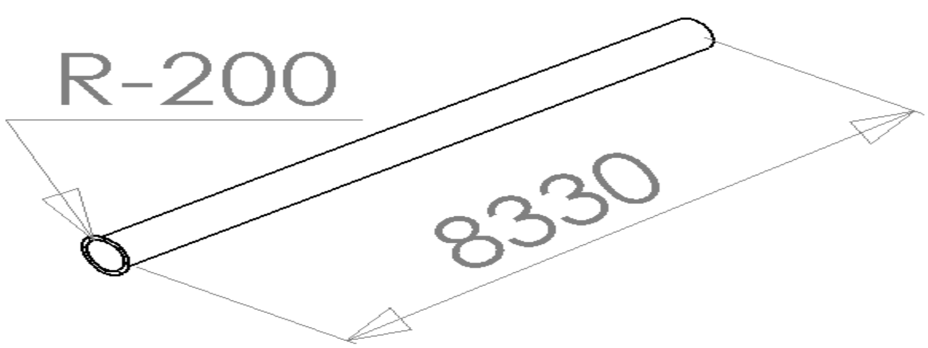
3.3. Additional forecasts from the future income growth of the HHs in the catchment

- **Freezers -----------------------------------**
- **Street lights --------------------------------**
- **Small clinic --- Kwh**
- **Cultural churches …………………………………………………….**
- **Irrigation ……………………………………………………………….**
- **Income type ………………………………………………………….**
- **The most agricultural plant**
- **Design drawing penstock section**



Penstock flange

Section of penstock pipe



Section of penstock with flange