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Wisdom at the source of Blue Nile

DESIGN OF MICRO HYDRO POWER SYSTEM

ON

TEMIE RIVER

BY:

DAWIT TESSEMA

BAHIR DAR UNIVERSITY

SCHOOL OF GRAGUATE STUDIES

SUSTAINABLE ENERGY ENGINEERING

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School Of Graduate Studies

Sustainable Energy Engineering

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By:

Dawit Tessema

Approval by the Board of Examiners

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ABSTRACT

Hydropower on a small scale is one of the most cost-effective energy technologies to be considered for rural electrification in Ethiopia. It is also the main prospect for future hydro developments. Where the large-scale opportunities either have been exploited already or would now be considered environmentally unacceptable. Whereas large hydro schemes often involve the construction of major dams and the flooding of whole valleys, micro hydro is one of the most environmentally benign energy technologies available.

The technology is extremely robust and systems to enhance the economic welfare of people in the rural areas, it is necessary to increase agricultural productivity and promote the development of rural enterprises. Both these approaches depend highly on the accessibility of commercial sources of energy. The promotion of micro hydropower system is expected to positively impact social welfare through improvements in health and education.

In terms of economic welfare, energy from micro hydropower system is expected to be beneficial for both producers and consumers in rural economies via the opportunities to create links between them and the national economy. However, the establishment of these plants requires initial as well as running costs and proper system as well as part design.

In Ethiopia, amhara region there are around thirty three suitable and deliberated areas for micro hydropower. From these, Temie River is one of the sites that have 1029 population who dwell around it without electric power access.

Currently the population that dwell around the site (Temie river) have used kerosene for lighting, diesel for pumps and grain mills, dry cell for radio for all with an idolized expense of 1218233ETB per year and also these current energy resources have their own negative impact on the environment.

So here on the thesis, system of micro hydropower plant on Temie River is design to replace these current energy resources of the community and to afford additional infrastructure for the better life style of the society like: - Television, Mobile charger, and libratory equipment for the health centre. At the end of the work the total expense of the society for energy is reduced by 18.91%, environmental pollution is decrease and improved the life style of the society as they get additional services.

Key words: - Micro hydro power design, Kerosene for lighting, economic welfare, Rural electrification in Ethiopia, Temie river, impact on the environment, lifestyle of the society.

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NOMENCLATURE

EEPCO	the Ethiopian Electric Power Corporation
ICS	Inter-connected system
SCS	Self Contained System
TPES	total primary energy source
Ktoe	kilo ton of oil equivalent
SNNPR	Southern Nations, Nationalities and Peoples' Regional State
EMF	electromotive force
AC	alternating current
PVC	Polyvinyl chloride
LED	light emitting diode
FRE	fiber reinforced epoxy
Pd	penstock design pressure
La	adjusted length
Fc	Friction Loss Correction Factor
PPA	power purchase agreements
NPV	Net Present Value
MHP	micro hydro power
KM	kilo meter
USD	United States dollar

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MW	mega watt
PV	photo voltaic
TWH	terra watt hour
KW	kilo watt
GWH	giga watt hour
Psi	pound per square inch
ETB	Ethiopian Birr
NGO	Non Governmental Organization
rpm	revolution per minute
PHP	Pico hydro power
TPES	total primary energy source
GTZ	Gesellschaft für Technische Zusammenarbeit
TJ	Terra Joule (1012)
ANRS	Amhara National and Regional State
O & M	Operational and maintenance cost.

CHAPTER ONE

INTRODUCTION

1.1. Background

Rapidly expanding global population and fast-paced economic growth, particularly in developing countries, are expected to propel demand for all forms of energy including electricity. To address the growing energy demand, countries are exploring a wide array of energy resources, including hydropower.

Hydropower is the most developed and widely utilized source of renewable energy. It is not only renewable but is also considered an economically viable alternative to electricity generated from fossil fuels. Due to clean and renewable nature of hydro energy, few countries across the world use it as the primary source of power supply. Several countries are offering financial support and adopting policies for promoting the hydropower sector. In particular, the focus is on development of environment friendly small-scale hydropower projects, which are considered ideal for rural electrification programs. However, the development of hydropower projects faces obstacles due to environmental concerns, and issues such as large-scale population displacement, and ecological damage.

Many rural communities in developing countries suffer the same symptoms; a never-ending cycle of poverty and lack of basic necessities. For many decades large aid organizations have focused on emergency relief without assessing the causes. It is the researcher belief that rural infrastructure development is a solution to these underpinning problems, and that, with the development of roads, safe water supplies and electricity. Communities can overcome the barriers to living long, safe and healthy lives.

The Ethiopian Electric Power Corporation (EEPCO), the sole electric power producer in the country, currently generates 2000MW where it comes from two different power supply systems, namely, the Inter-connected system (ICS) and Self Contained System (SCS). ICS is mainly supplied from hydro-power plants as well as geothermal power plant. Whereas, SCS consist of mini hydro-power plants and a number of isolated diesel generating units widely spread all over the country. The country is toiling to maximize its power generation capacity with the expectation of reaching 8000 to 10000MW in the coming five year up on the completion of the started hydropower plants [10].

Considering the stated figure for the country which has population of over 73.9 million people one can evidently see that the power provision in the country is at its scanty stage. In addition, since most areas of the country are not connected to the national electric grid, and as the power to the grid is insufficient, thus, rural areas are rely on kerosene and traditional fuel wood biomass to meet their energy demand, both for cooking and lighting. This unsustainable use of energy has for long been damaging to the environment and the human life. Therefore these negative effects of fossil fuels on the local and global environment oblige to search for other alternatives.

In Ethiopia there is a vast energy resource potential, which, if employed, could reduce the present energy crisis prevailing in the country and increase the process of rural electrification. From these renewable energies, Hydropower is the most abundant.

Hydropower plants are plants used to generate electric power by capturing the energy released by water falling through a vertical distance, and transform this energy into useful electricity. In general, falling water is channelled through a turbine which converts the water's energy into mechanical power. The rotation of the water turbines is transferred to a generator which produces electricity. However, the technically exploitable potential of hydropower is reduced by environmental, economical and geological factors. Facilities range in size from large power plants that supply many consumers with electricity to small and micro plants that individuals operate for their own energy needs or to sell power to utilities.

1.2. Statement of the Problem

In Ethiopia, particularly in amhara region there are around thirty three suitable and deliberated areas for micro hydropower [9], but still now no one is go ahead for implementation. From these, Temie river is one of the site that have 1029 population who dwell around it far from the central grid connection without any electric power access. And the population have costed idolized expense for power that is over the economy of the society, See the table 1.1. The cost of these current means of power source is registered from the site.

Table 1.1: Current Cost Breaks Down and Total Consumption per Year.

Type of Fuel	Consumption per year	Unit Price(ETB)	Total cost (ETB) per year	Remarks
Kerosene	5654.8 litter	20.94	118,411.9	For lighting. the cost registered on August 16, 2011
Diesel	16897.1 litter	13.47	227,603.66	For milling and pumps. the cost registered on August 16, 2011
Dry Cell	218055	4	872,217.00	For radio. the cost registered on August 16, 2011
Total			**1,218,233.00**	

As see from the above table 1.1 these people currently outlay 1218233ETB per year for power case and these power sources have great impact on the environment as well as on the health of the society and also by these power source they can't undergo their health centre treatment efficiently and they are limited to utilize TV, fridge, and like for better life style in general they can't satisfy their needs with these current energy resources..

1.3. Objectives

The general objective of this thesis is design of micro hydropower system for rural electrification on Temie River.

The specific objectives are:

- Design and sizing of parts of micro hydropower
- Calculate the total load demand of the selected site area population.
- Address economic analysis of the whole system.
- Put side by side micro hydro power total expense throughout the life span to the current energy source of the site.

1.4. Scope and Limitation of the Study

The site selected for this work is located far from the national electric grid so that the electric source that is going to be designed should be a standalone system. In order to achieve this need there are different alternatives configurations, such as;

- Hydro hybrid system with other renewable or non renewable source especially with PV system or wind power.
- Hydro with battery storage system,
- Hydro without any storage or backup source by increasing the load factor and by designing the system for the peak load of the site demand.

Hydro hybrid with others sources such as PV, Wind, diesel and the like needs a series of analysis to determine the possible combination of each sources for a given demand, in addition to reduce the scope of the work, the thesis exclude this alternatives from comparison, only design stand alone micro hydropower system, this can be taken as the limitation of this work. And the other limitation is the design mainly focused on the turbine and penstock parts; this is due to lack of time and allocated fund. And finally the thesis is limited in its scope on the design of micro hydro power for rural electrification.

1.5. **Organization of the Thesis**

Chapter one describes general introduction and motivation as well as statement of the problem of the thesis. Chapter two reviews literatures about SNNPR and Tungu Kabri micro hydro power plant and Master plan of mini/micro hydropower to replace diesel power plants. Chapter three presents the basic components of micro hydropower. In Chapter four, the criteria used in selecting a suitable site is describe and some elaboration about the site and the total load is calculated. Chapter five presents system design analysis of micro hydro power plant. Chapter six presents the installation and further economic analysis of the micro hydropower model. Chapter seven describe about result and discussion on the work done on the above chapter. Finally chapter eight is elaborate conclusion and recommendation of the thesis.

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CHAPTER TWO

LITERATURE REVIEW

2.1. World Electric Power Sources and Their Potential

The Production of electricity in the world in year 2008 was 20,261TWh which was 11% of solar energy the earth receive in one hour (174,000TWh). Sources of Electricity were Fossil Fuel 67%, Renewable Energy 18% and Nuclear Power 13%. Majority of Fossil Fuel usage for the generation of electricity were of Coal and Gas, Oil was only 5.5%. 92% of renewable energy was from Hydroelectric followed by Wind 6% and Geothermal 1.8%. Solar Photovoltaic was 0.06%, Solar Thermal was 0.004% [22].

Table 2.1: Source of Electricity [22]

	Coal	Oil	Natural Gas	Nuclear	Hydro	other	Total
Electricity (TWｈ/year)	8,263	1,111	4,301	2,731	3,288	568	20,261
proportion	41%	5%	21%	13%	16%	3%	100%

Total Energy consumed at all power plants for the generation of electricity was 4,398,768 ktoe (kilo ton of oil equivalent) which was 36% of total primary energy source(TPES) of year 2008. Electricity Output (gross) was 1,735,579 ktoe (20,185TWｈ), efficiency was 39%, balance of 61% was heat generated. Small part(145,141 ktoe, which was 3% of input total) of heat was utilized at co-generation heat and power plants. There were in-house consumption of electricity and power transmission loss of 289,681 ktoe. Supply to the final consumer was 1,445,285 ktoe (16,430 TWｈ) which was 33% of total energy consumed at power plants and heat and power co-generation (CHP) plants [22]. As see from table 1.1, next to coal and natural gas world populations are getting their electric power from hydropower.

Hydro power

Close to a quarter of the energy of the sun that reaches the earth's surface causes water to evaporate and hence a proportion of this energy causes vapor to rise against the earth's gravitational pull. This vapor then condenses into rain and snow, which again falls back to the earth's surface. This is called the water cycle and is the fundamental reason why hydropower is possible. When rain and snow fall onto any ground above sea level some of the sun's energy is conserved in the form of potential energy. This energy is then dissipated in currents as water runs down in streams. By catching this water in the controlled form of pipes, we can exploit the kinetic energy that becomes available with the movement of water. These pipes are then used to direct the stream of water, under pressure, onto a turbine blade. The water then strikes the turbine blade to create mechanical energy. This mechanical energy is then transmitted to an electrical generator through a rotating shaft. This simple process is essentially how all hydropower is generated – a process tried and tested over hundreds of years which currently supplies over 715,000 MW or 19% of the world's total electricity. [20]

Hydropower is actually generated quite simply, if there is a kinetic energy of the water. Because water is 500 times as dense as air. Even a slow stream will generate power as a result. When the water moves through a dame, or a confined space, it begins to rush faster as a result of more water going through a smaller space. When it does this, it turns turbines that then help to power a generator. The generator then sends power into batteries and converters in order to send power out or store it.

Advantages of Hydropower

- Unlike fossil fuels, where oil, coal and natural gas have to be taken out of the ground, water is all around us and whether we use it or not, it is moving by and creating energy. Hence, there is no cost of fuel with hydropower.

- As well, fossil-fuel fired plants require a lot of service and only last about 50 years. However, hydropower plants that were built 100 years ago are still in generation, making them much more cost effective. Dams and other hydropower plants also use less people on site, thereby lowering costs even more.

- As has been mentioned, hydroelectric plants and dams do not burn fossil fuels and therefore do not contribute to greenhouse gases and climate change. The only greenhouse gases that are produced by the plant and dam are those that are emitted during its construction, which are easily offset within a few months of the dam or plant's use.

World largest hydropower plants

In terms of the generation of hydroelectric power, those countries with many rivers generally lead the way in power generation. China is the number one producer of hydropower in the world with 563 terawatt hours. While the Brazil, Canada and the United States come in second, third and fourth respectively. Of those countries, Brazil and Canada use hydropower to handle 85 and 61 percent of their power needs. Hydropower takes care of 17 and five percent of the power needs of China and the United States respectively. Norway on the other hand produces 135 terawatt hours of hydropower that is 99 percent of its energy needs [21].

Table2.2: The Exploited Largest Hydropower Plants on Earth [21]

No.	Name of Dam	Country	Year of completion	Total Capacity(MW)
1	Three Gorges Dam	China	2009	22,500
2	Itaipu	Brazil/Paraguay	1984,1991,2003	14,000
3	Gun(Simon Bolvar)	Venezuela	1986	10,200
4	Tucumu	Brazil	1984	8,370
5	Sayano shushenskaya	Russia	1985,1989	6,400
6	Krasno yarskaya	Russia	1972	6,000
7	Grand coulee	United states	1942,1980	6,809
8	Robert-Bourassa	Quebec, Canada	1981	5,616
9	Churchill falls	Canada	1971	5,429
10	Longtan Dam	China	2009	6,300

As the world's energy consumption explodes, no one can argue that there is a growing need to find an alternative to fossil fuels. The need for renewable, environmentally friendly power sources grows more apparent every day. Among the renewable resources being investigated and implemented, hydroelectric power plant is the one. Hydro electric power has proven to be a clean, viable renewable resource with many benefits. All the renewable resources in the world, hydroelectric power is by far the most widely used. In fact, in 2005, an estimated 20% of the world's electricity was supplied by hydroelectric power. That's an impressive amount of power and should not be underestimated [21].

2.2. Electrification in Ethiopia

Ethiopia is located in the eastern part of Africa between 3^o to 15^o north and 33^o to 48^o east. With a surface area of 1.1 million square kilometers, it is the third largest country in Africa. It is the second most populous country in Sub Saharan Africa with an estimated population of about 73.9 million, which is mostly distributed in northern, central and southwestern highlands. There is a vast energy resource potential in Ethiopia, which, if employed, could reduce the present energy crisis prevailing in the country and increase the process of rural electrification. The total exploitable renewable energy that can be derived annually is from primary solar radiation, wind, forest biomass, hydropower, animal waste, crop residue and human waste [3].

Table 2.3: Different Energy Resources in Ethiopia [17]

Type	Exploitable Reserves	Units	Exploited percent
Hydropower	30,000	MW	0.9%
Solar/day	5	KWh/m^2	~ 0%
Wind speed	3.5-5.5	m/s	~ 0%
Geothermal	700	MW	~ 0%
wood	1120	Million tones	50%
Agricultural west	15-20	Million tones	30%
Natural gas	75	Billion m^3	0%
Coal	13.7	Million tones	0%

As see from the table 1.3, Energy supply and consumption in Ethiopia is characterized by the predominance of traditional fuels in the form of fuel wood and agricultural residue including dung as the majority of people in Ethiopia live in the rural areas (85%) and depends on these sources of energy for cooking, lighting and heating. More than 97% of the energy used in the households is in the form of biomass energy (fuel wood and agricultural residue). Further, energy use in households is characterized by a very low efficiency of 5 to 10%, which could readily be improved with appropriate intervention measures. It is only a minority of households that has access to modern fuels like kerosene and electricity (1% of the rural population has access to electricity, leaving the rest is without access.). Approximately 13% of the population are connected to the electric grid and are virtually all clients of EEPCO concentrated in the main urban areas [3].

Potential of Hydropower in Ethiopia

From the total covered area i.e. 1.1044X10km^2, 104,300 km^2 is covered with water. From which for the coming five year planned to generate 9000MW electricity. Large hydro power makes up 98% of Ethiopia's power production. The government has large expansion plans for large hydro power to stop energy shortages and to eventually become an energy exporter in 2010[13]. Concerning rural electrification, the Ethiopian government has set the target to connect 50% of the households to the electricity grid.

The theoretical potential of hydropower in Ethiopia is estimated to be in 30,000-45,000 MW which would enable an annual 160,000 GWh. The estimated economically exploitable hydropower potential ranges between 15,000 and 30,000 MW [13].

Table 2.4: Hydropower Potential of Ethiopia [5]

Name of river basin	Name of potential site					
	Small Scale <40 MW	Medium Scale 40-60MW	Large Scale >60MW	Total	Technical Hydropower potential (GWh/year)	Percentage share of the Total%
Abbay	74	11	44	129	78,800	48.9
Rift valley Lakes	7	-	1	8	800	0.5
Awash	33	2	-	35	4,500	2.8
Omo - Gibe	4	-	16	20	35,000	22.7
Genale- dawa	18	4	9	31	9,300	5.8
Wabe shebelle	9	4	3	16	5,400	3.4
Baro Akabo	17	3	21	41	18,900	11.7
Tekeze-Angereb	11	1	8	20	6,000	4.2
Total	173	25	100	300	159, 300	100%

Table 2.5: Installed Hydropower Potential of Ethiopia [3]

Name	Installed capacity	Commissioning	Basin	Contractor	Financing	Cost	Remarks
Fincha	134 MW	1973	Fincha(Blue Nile)				also for irrigation
Gilgel Gibe I	180 MW	2004	Omo River	Salini (bid)	World Bank	$331m	
Tekezé	300 MW	2009	Tekeze (Atbara)	Sinohydro Corporation (bid)	Chinese	$365m	Out of production because of drought; also for irrigation
Beles	460 MW	2010	LakeTana	Salini	Ethiopian		Irrigation of

			(Blue Nile)	(nobid)	governmen		140,000 ha out of
GilgelGibe II	420 MW	2010	OmoRiver (nodam,fed by GG I)	Salini (nobid)	Italy and EIB	Euro 370m	production because of collapsed tunnel
GilgelGibe III	1870 MW	2012-13	Omo River	Salini (nobid)	Italy	Euro 1.55bn	faces stiff environmental criticism
Fincha Amerti Nesse (FAN)	100 MW	planned	Fincha (BlueNile)	China Gezhouba Group Co.(CGGC)	Exam Bankof China	$276m	
Halele Worabese	440 MW	2014	Omo River	Sinohydro Corporation	Fair Fund?	Euro 470m	
GilgelGibe IV	2000 MW	2014	tributaryof theOmo River	Sinohydro Corporation	Chinese	$1.9bn	
Chemoga Yeda	278 MW	2013	tributaryof theBlue Nile, nearDebre Markos	Sinohydro Corporation	Chinese	$555m	Willconsist of 5 interconnected dams
Genale Dawa III	256 MW	awarded in 2009	between Oromoand Somali state	Chinese CGGC	Chinese	$408m	Feasibility study by Lahmeyer with funding from the AfDB

As can be seen from tables 1.5, Ethiopia has abundant installed hydropower resources that have a potential to overcome poverty. And as see from table 1.4, hydropower potential of Ethiopia is classified in three groups these are large scale, medium scale and small scale hydropower. From these, small scale hydropower is vital for the country side area because small scale hydropower is needs less capital cost, less installation as well as maintenance knowledge, and also generate from small discharge rate (flow rate) and can plant for a village or a kebelle based on the output power and demand rate. Small scale hydro powers are like small hydropower, micro hydropower and Pico hydropower (see appendix - F).

2.3. Micro Hydropower

Supply of energy in a suitable form is considered to be one of the main inputs required to raise the standards of living of the people and to minimize the damage to the ecosystem. Supplying improved energy services to people for the first time is difficult; but supplying such services profitably to very poor people who live far away from roads and the electricity grid pose a particularly difficult challenge. However micro hydro compares well with other energy supply technologies in these difficult markets. But despite this, micro hydro appears to have been relatively neglected by donors, the private sector and governments in the allocation of resources and attention. In the past rural electrification by means of grid extension was the option favored by donors.

Micro-hydro is the small scale harnessing of energy from falling water, generating typically less than 100 KW and powering small communities or factories. Micro-Hydro power systems are relatively small power sources that are appropriate in most causes for individual users or groups of users who are independent of the electricity supply grid.

Micro-hydro power system can using waste water from community means that neither a large dam is built nor is land flooded. Only waste water from different parts of the city is required to generate power and this has minimum environmental impact. After water treatment techniques, we can provide chemical less water to formers to serve the land of the country. The amount of energy that can be captured depends on the amount of waste water flowing per second (the flow rate) and the height from which the waste water flows through sewage pipes.

2.3.1. Micro hydro power potential of Ethiopia

Ethiopia is one of the lowest electrification levels in the sub-Saharan Africa. The rural electrification level is less than 1.5 percent which is the lowest in the world. After more than a century of history, the benefits of electricity are still limited to a small section of the population in urban areas [12].

The Chinese study for the ministry of agriculture, 1989 was exploration level of small hydropower site in the western, central and south-western parts of the country, a total of 3,138kw where identified with the micro hydro range. Ethiopia electric Agency, 2003 the theoretical potential in the micro hydro range is estimated to be about 100MW. This potential is states as indicated below.

Table 2.6: Micro Hydro Power Potential of Ethiopia by Region [12]

Micro hydro power potential by region	
Region	Capacity(MW)
Oromia	35
Amhara	33
SNNP	18
Benshangul-gumeze	12
Gambella	2
Total:	100

As shown in the above table the total hydropower potential in Ethiopia is estimated to be about 100MW.Assuming 150 to 200 watt demand per household, this could mean about 0.5 million households could be electrified with micro hydropower.

Micro-Hydro Advantages

There are many advantages to micro-hydro power besides being an efficient and renewable energy resource:-

- Micro-hydro requires relatively little flow and head to produce electricity
- In addition, it generates a more reliable supply of electricity when compared to other home-sized renewable energy systems
- Its peak energy period is in winter when greater levels of electricity are generally needed and solar power is diminished
- Unlike large-scale hydroelectric plants, is considered a very environmentally friendly choice because of its minute effect on the ecosystem—water passes through the system and back into the river or stream with little or no impact on the waterway.

Micro-Hydro Disadvantages

Micro-hydro has many advantages over conventional grid power, as well as over solar and wind power, but it does have a few disadvantages to consider:-

- Not everyone has a suitable site a reliable, year-round water source is needed. Remoteness of the power source from the home, as well as the quality of your water source unlike solar and wind systems where you can add modules or a larger turbine.

2.4. Previous Works

2.4.1. SNNPR micro hydro power [3]

In the Southern Nations, Nationalities and Peoples' Regional State (SNNPR) OF ETHIOPIA, there exist three smaller hydropower schemes in Yadot (350 kW), Dembi (750 kW) and Sor (5 MW). Currently GTZ is supporting 4 off-grid sites (7, 30, 35, and 50 kW) and 1 grid-connected site (200 kW). For example, the Gobecho I micro hydropower plant is built on a small river in Bona *Zuria* woreda of the Sidama zone in SNNP state with over 50,000 Euro; this project can generate about 7 kilowatts of energy and provides electric power to more than 5,000 residents of the woreda. The construction of Gobecho II and Erete micro hydropower plant is underway.

And also Residents of Yaye town in the Abegona woreda, in collaboration with the Irish Development Cooperation, built a micro hydro-power plant (MHP) at a cost of seven million birr. The MHP, Which was built in 2005, has the capacity to generate 150 KW electric powers. Owned by the Sidama Development Cooperation of the MHP was set to provide electric power for Yaye town for 20 years, As Yaye was not connected to the nation's electric power grid. The MHP has been supplying power to the town. However, after serving the community for two years the plant was shut down when the Ethiopian Electric Power Corporation (EEPCO) extended the national power grid to Yaye. Since there is no power purchase agreement that allows the private sector to feed the national power grid, the Yaye MHP ceased operation.Hydropower, large and small, remains by far the most important of the renewable energy resources for electrical power production in worldwide, providing 19 percent of the planet's electricity.

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MHP is an installation where hydraulic power is used to generate small quantities of electricity by means of one or more turbine generators where a national grid does not extend. MHP can supply power to a rural community, or to one industry, hospital, and tourist site. A long time ago Ethiopia named itself the water tower of Africa because of its potential to generate 45,000 MW of power. At the moment the country is producing 2000MW. Electricity coverage is 15 percent. Electricity supply in rural areas where the majority of the populations (85 percent) live is estimated at one percent. As a result the majority population depends on biomass fuels for cooking, lighting and space heating. The heavy reliance on biomass fuels in rural areas has led to detrimental consequences to local environment in terms deforestation, bio diversity, water quality, soil degradation and erosion.

Micro hydropower was a practical and potentially low-cost option for generating electricity at remote cities, particularly for small villages in hilly areas. Running costs of such schemes were very low. However, the initial cost could be relatively high. A recent study indicates that an economically feasible hydropower potential of Ethiopia is estimated at 15,000 to 30,000 MW and ten percent of this amount was suitable for small-scale development.

The Evangelical Church Mekaneyesus has installed many micro hydro turbines used for flour milling in some rural areas. Though the MHPs are useful they are facing several problems. The Yaye MHP is not the only plant that was closed. About ten hydropower systems were installed by the government for electric generation, out of which nine have ceased operation. One of the major reasons for the failure of these plants is lack of technical capability to maintain or recondition the installations. shutdown micro hydro installations were built on completely imported hard ware's and were installed by the help of highly-paid foreign experts. The former national utility, the Ethiopian Electric Power Authority, many years ago used to install and operate a number of small hydropower stations. The stations were used to supply towns in isolated mode until the 1990s.When the inter-connected system was brought to the towns the importance of the micro hydro systems was drastically reduced. Many of the hydro-systems were installed in the 1950s and 1960s were unreliable and extremely costly to operate.

Ethiopia is building huge hydropower projects in an effort to boost electricity supply that can satisfy the local demand. —Communities can generate income from MHPs. At the time of the national grid extended to that region, the Yaye MHP was closed. But now it connects to the grid and again servicing to the society.

2.4.2. Tungu Kabri micro hydropower [24]

The Tungu-Kabiri community micro hydo power project in the rural area around Mount Kenya demonstrates how the use of micro hydropower can bring development to rural areas in Africa. About 96% of the rural population in Kenya still lack access to grid-based electricity. A pilot project initiated by Practical Action (previously Intermediate Technology Development Group ITDG) in Kenya has shown the potential for decentralised micro hydro schemes to provide access to electricity. In Tungu-Kabiri, rural Kenya, almost 200 households came together and formed a commercial enterprise to own and operate a micro hydropower plant, which they constructed and continue to maintain themselves. The micro hydro plant now supplies electricity to a number of local enterprises and households, greatly improving quality of life in the area.

Only 4% of people in rural Kenya currently have access to grid-based electricity. Families instead mainly rely on kerosene for lighting, woodfuel and dung for cooking, and diesel-powered systems for tasks such as milling grain. Cooking with traditional biomass causes severe air-pollution and health problems and takes considerable time and effort to collect fuel. Purchasing kerosene may take up about 1/3 of a rural family's income.

In 1998 ITDG in collaboration with the Kenyan Ministry Energy (MoE) and with funding from the UNDP, undertook a pilot project to illustrate the potential for decentralised micro hydro schemes to address the lack of electricity. After an initial feasibility study, the Tungu-Kabiti community 185 km north of Nairobi was chosen as the site for the pilot project.

About 200 members of this community came together and formed a commercial enterprise to own, operate and maintain a micro hydropower plant. Each individual bought a share in the company, with a maximum share value of about US$50. The members also contributed labour, dedicating every Tuesday for over a year to the construction work, which was overseen by the MoE and ITDG. Involving the community in all aspects of project development from the start was critical to reduce local technical barriers and it ensured that the community could effectively maintain and repair the micro hydropower system themselves. The micro hydropower plant is owned and managed by the community, and this complete community ownership has been central to the project's success.

The day-to-day operations of the plant are managed by a 10-member community power committee, and this committee also conducts consultations with the wider community about how the power generated from the system should be used. The electricity is currently used mainly for micro-enterprises, such as a welding unit, a battery-charging station and a beauty salon. This project has shown that micro hydropower can effectively meet the energy needs of poor off-grid communities. It has demonstrated that communities are willing to invest time and money for improved energy services, and can organize themselves to build and operate a micro hydropower plant.

2.4.3. Master plan of mini/micro hydropower to replace diesel power plants [28]

Master plan of mini/micro hydropower to replace diesel power plants was carried out by TEAM Consulting Engineer Co,Ltd. and submitted to NEA in August 1983. The purpose of the study's to identify promising mini/micro-hydropower projects to replace the existing diesels power plants scattered throughout rural Thailand. The aim of the study is to find a long-term solution to the costly electricity generation by the diesel power Plants which depend on imported oil. Altogether, there are 40 potential mini/micro hydropower sites. Among these, 29 sites were justified economically suitable for further detailed feasibility study and engineering works. The selection of the sites was done primarily based on 1:50,000 topographic maps prepared by the Royal Thai Survey Department and then was checked by field surveys. Layout of project components was made for each selected site. These project components include a low head diversion weir, an intake to the conveyance channel, a penstock and a power house. The hydrologic study was carried out on the basis of regional approach. Regional flow duration curves for the Northern, Northeastern and Southern regions were developed from available stream flow records. Cost estimation of each selected mini/micro hydropower project was based on the quantity estimates of the typical layout with key dimensions varied from site to site. In conducting economic justification of the hydropower projects, two bases were considered. For the isolated system, comparison with the diesel power plant was made. Only one project was evaluated with this basis.

In case of interconnected system, the economic justification was undertaken on the basis of comparison between the system which would be supplied by the national power system of EGAT alone and the system which would be supplied by the national power system of EGAT with power reinforcement by the mini/micro hydropower project. It was recommended that the 29 sites which were considered economically feasible should be subjected for further work and detailed engineering layouts and designs should be undertaken together with the revision of the economic feasibility study with more accurate cost estimates. For those remaining sites, it was still recommended that those load centers be hooked-up to the national transmission grid because they would be more economical than utilizing existing diesel plants.

When come up to current study nothing like that of yaye town, the selected site area that mountainous (2300 meter altitude) and remote area, is difficult to have time extending national grid to it even in the future. That is why micro hydropower is the vital plant to electrify the site. And also to overcome the problem of luck of maintenance human power (technician) as well as to down frequency of accidental trouble on the plant, the work is carried out with better efficiency. In addition to this, like that of Tungu-Kabiri, rural Kenya project, the designer (researcher) is native of the country and dwelling around there, there for, it is simple to trains the household, in order to carried out the construction as well as the maintain by themselves, and to take visual inspection. The work of the thesis is to replace kerosene for lighting and diesel for power system with micro hydro power that is great change to the society because they will get additional access that haven't currently like television and clinic laboratory equipments.

CHAPTER THREE

BASIC COMPONENTS OF MICRO HYDROPOWER

The figure 3.1 below shows that the basic components of a Micro Hydropower system on Temie river. This system configuration is known as ―Run of river‖ since the water that flows through the turbine is not take away beyond what is necessary for short tern head regulation. This lets the river run on depending on weather and power production not reservoir storage. Excess flow bypasses the water diversion intake so that the eco system between the power house tail race and diversion intake is left intact.

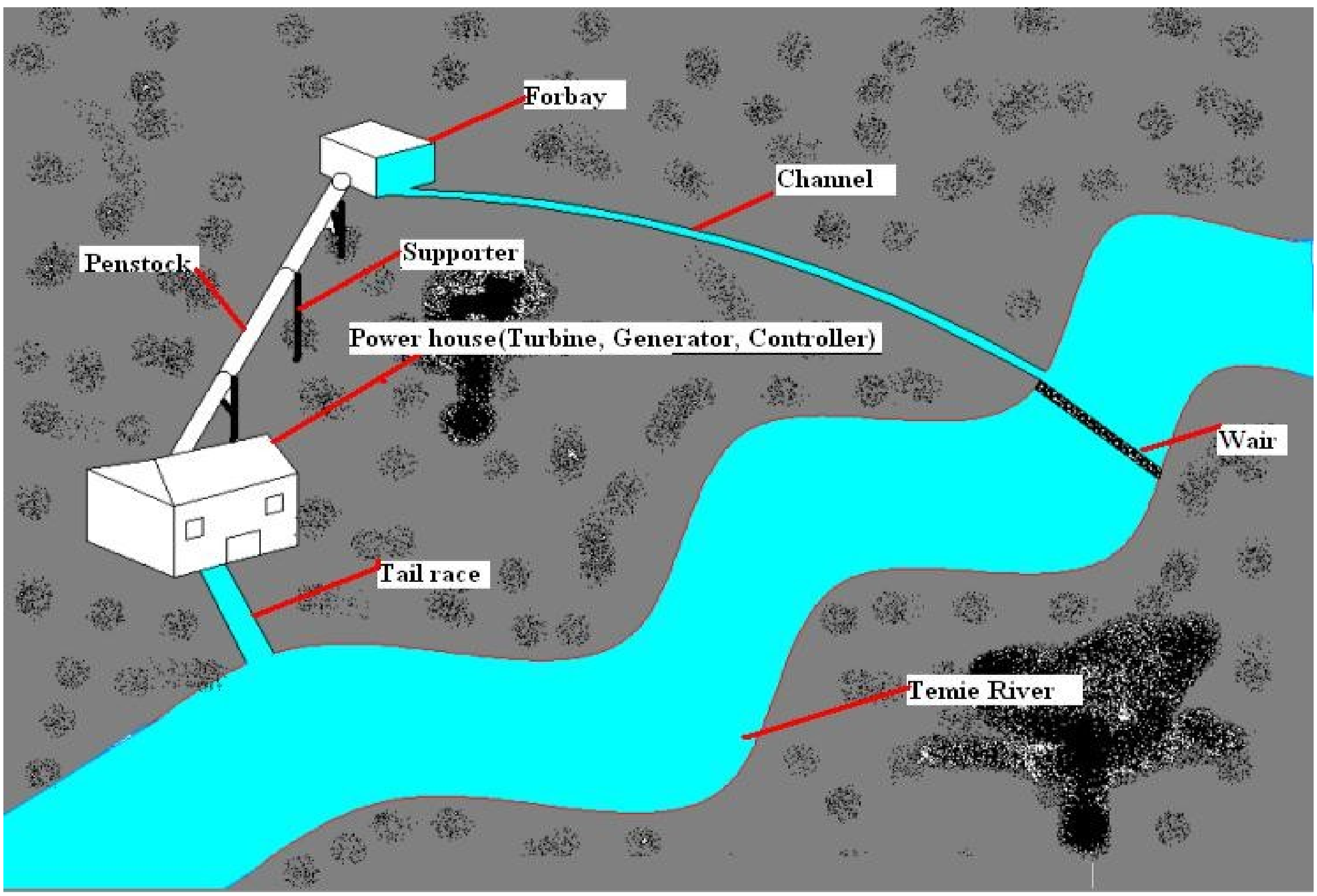

Figure 3.1: Micro Hydro Power System Components

The various components of micro hydro power plants are:-

3.1 Civil Components

A hydropower station has to divert water from the river. To perform this function civil structures are necessary. These components are:-

Weir: - A hydro system must extract water from the river in a reliable and controllable way. The water flowing in the channel must be regulated during high river flow and low flow conditions. A weir can be used to raise the water level and ensure a constant supply to the intake. Sometimes it is possible to avoid building a weir by using natural features of the river.

Usually it is sensible to adopt traditional water management techniques known to local people. Temporary weir construction might be one of these techniques. The principle of the temporary weir is to construct a simple structure at low cost using local labour, skills and materials. It is expected to be destroyed by annual or bi-annual flooding. Advanced planning is made for rebuilding of the weir whenever necessary. There are various types of weir in use. Like:-

- Broad crested weir (or broad-crested weir)
- Sharp crested weir
- Crump weir (named after the designer)
- Needle dam
- Proportional weir
- Combination weir
- MF weir
- V-notch weir
- Rectangular weir
- Cipolletti (trapezoidal) weir
- Labyrinth weir
- Tidal weir
- Long crested weir - e.g. Duckbill and diagonal
- Minimum Energy Loss weir.

The classification of weirs may be done is number of ways .like based on function:-

Storage weir: They are constructed purely for storing water. They are termed as low dams also.
Pick-up weirs: In a storage project the reservoir water is discharge in the river through supply sluices. This released water is picked up by constructing a weir a cross the river where canals take off a series of such pick-up weirs may be constructed to utilize the available water
Intake weir: They are constructed as a part of head works. They raise the water level by obstructing the river flow. The water is then diverted to the canal.
Waste Weirs: They are generally used as spill ways for reservoirs. It protects the reservoir and the main storage dam (Sahasrabudhe 1994) under this intake weir is selected.

Channels:-The channel conducts the water from the intake to the fore bay tank. The length of the channel depends on local conditions. In one case a long channel combined with a short penstock can be cheaper or necessary, while in other cases a combination of short channel with long penstock suits better.

Most channels are excavated, while sometimes structures like aqueduct are necessary. To reduce friction and prevent leakages channels are often sealed with cement, clay or polythene sheet.
Size and shape of a channel are often a compromise between costs and reduced head. As water flows in the channel, it loses energy in the process of sliding past the walls and base material. The rougher the material, the greater the friction loss and the higher the head drop needed between channel entry and exit. Where small streams cross the path of the channel very great care must be taken to protect the channel. A heavy storm may create a torrent easily capable of washing the channel away.

Forebay tank: - The forebay tank forms the connection between the channel and the penstock. The main purpose is to allow the last particles to settle down before the water enters the penstock. Depending on its size it can also serve as a reservoir to store water. A sluice will make it possible to close the entrance to the penstock. In front of the penstock a trash rack need to be installed to prevent large particles to enter the penstock.

Penstock: - The penstock is the pipe which conveys water under pressure from the forebay tank to the turbine. The penstock often constitutes a major expense in the total micro hydro budget. The trade-off is between head loss and capital cost. Head loss due to friction in the pipe decreases dramatically with increasing pipe diameter. Conversely, pipe costs increase steeply with diameter. Therefore a compromise between cost and performance is required. The design viewpoint is first to identify available pipe options, then to select a target head loss, 5 % of the gross head being a good starting point. The details of the pipes with losses close to this target are compared for cost effectiveness. A smaller penstock may save on capital costs, but the extra head loss may account for lost revenue from generated electricity each year.

Power house - a small shed or enclosure to protect the water turbine and generator from the elements. The basic objective of power house planning is to house all the equipments suitably in a structural complex.

Types of Power House Planning

The basic requirement of power house planning is a functional efficiency coupled with aesthetic beauty.
A power house can be classified as:

- surface power house: the power house is located in a building above the ground
- Underground power house: in this type of power house the power house carven, tunnels and shafts for water conduits system, access tunnels and ventilation shafts are located inside the mountain.

The geology of the rock strata should be such that various underground structures are able to stand on their own without support. In recent years more and more underground power stations has come has come in to practice .This is so because rapid development in rock mechanics , mechanized tunnelling and mucking removal and lining equipment have made tunnelling both economical and rapid .
On the other hand there has been rapid increasing in the cost of steel which has made surface power scheme less attractive.

Selection of Site for Power House Planning

The site selection for the power house is based on the following criteria:

1. To provide maximum available head.

2. To minimize cost of construction and excavation.
3. To get easy access to the power plant.

3.2. Mechanical components

3.2.1 T**urbines**: - Hydraulic Turbines are being used from very ancient times to harness the energy stored in flowing streams, rivers and lakes. The oldest and the simplest form of a Hydraulic Turbine was the Waterwheel used for grinding grains. Different types of Hydraulic Turbines were developed with the increasing need for power. In general turbine is rotating mechanical device, which transfers the kinetic energy of water to mechanical energy by means of a rotation of a shaft.

Table 3.1: Classification of Hydraulic Turbine

Classification of Hydraulic Turbine

	Classification criteria	
No.	Based on flow path	Based on pressure change
1	Axial flow	Impulse
2	Radial flow	Reaction
3	Mixed flow	

In a reaction turbine the runners are fully immersed in water and are enclosed in a pressure casing. The runner blades are angled so that pressure differences across them create lift forces, like those on aircraft wings, and the lift forces cause the runner to rotate.

In an impulse turbine the runner operates in air, and is turned by one or multiple jets of water which make contract with the blade. A nozzle converts the pressurized low velocity water into a high speed jet.

Turgo Turbines

Figure 3. 2: Turgo Style Wheel [8]

Turgo turbine is an impulse type of turbine in which a jet of water strikes the turbine blades. The structure of a Turgo wheel is much like that of airplane turbine in which the hub is surrounded by a series of curved vanes. These vanes catch the water as it flows through the turbine causing the hub and shaft to turn. Turgo turbines are designed for higher speeds than Pelton turbines and usually have smaller diameters.

Pelton Turbines

Figure 3. 3: Pelton Turbine Style Wheel [8]

A Pelton turbine is also an impulse turbine but in this type of turbine the hub is surrounded by a series of cups or buckets which catch the water. The buckets are split into two halves so that the central area does not act as a dead spot incapable of deflecting water away from the oncoming jet. The cutaway on the lower lips allows the following bucket to move further before cutting off the jet propelling the bucket ahead of it. This also permits a smoother entrance of the bucket into the water jet.

Cross-Flow Turbines

Figure 3. 4: Cross-Flow Turbines Style Wheel [8]

A cross-flow turbine, also sometimes called a Michell-Banki turbine (from the name of the manufacturer) is a turbine that uses a drum shaped runner. A vertical rectangular nozzle is used with this type of turbine to drive a jet of water along the full length of the runner. One advantage of this type of turbine is that it can be used in situations where you have significant flow but not enough head pressure to use a high head turbine.

Francis Turbine

Figure 3.6: Francis Turbine Style Wheel [8]

The Francis type of turbine is a reaction type of turbine in which the entire wheel assembly is immersed in water and surrounded by a pressure casing. In a Francis turbine the pressure casing is spiral shaped and is tapered to distribute water uniformly around the entire perimeter of the runner. It uses guide vanes to ensure that water is fed into the runners at the correct angle.

Propeller Turbine

Figure 3.7: Propeller Turbine Style Wheel [8]

A propeller turbine is just what its name implies. It uses a runner shaped just like a boat propeller to turn the generator. The propeller usually has six vanes. A variation of the propeller turbine is the Kaplan turbine in which the pitch of the propeller blades is adjustable. This type of turbine is often used in large hydroelectric plants. An advantage of propeller type of turbines is that they can be used in very low head conditions provided there is enough flow.

Water nozzle - a nozzle which shoots a jet of water (impulse type of turbines only)

Generator shaft - a power transmission part that connects the runner to the generator.

Governor - The governor is a mechanism of controlling the rotational speed of the turbo generator units .Constant speed must be maintained in order to obtain alternating current supply with a constant frequency as the turbine and its inter connected generator tends to decrease or increase speed as the load varies .The maintenance of almost constant speed requires the turbine by closing or opening the gate or nozzle of the turbine automatically through the action of the governor.

Drive System: - Transmits power from the turbine shaft to the generator shaft or the shaft powering other devices. It also has the function of changing the rotational speed from the one shaft to another when the turbine speed differs from the required speed of the alternator or device.

3.3. Electrical components:

The main electrical components relevant for MHP plants are the generator, or an induction motor used as a generator, the electric load controller, the electric power network, including conductors, insulators, electricity meters etc., and the transformers. The following system structure shows the basic elements:

One generator ⇒ one step-up transformer ⇒ transmission line ⇒ several step-down transformers ⇒ distribution lines.

Electrical Generator: - is a device that generates electricity from mechanical energy, usually via electromagnetic induction. Electromagnetic induction works by forcibly moving a loop of wire (a rotor) around a stationary bar (a stator) that provides an electric field, either through a permanent magnet or an electromagnet. By Faraday's law, this induces a current in the rotor, which can be used to power machinery or charge batteries. Possible sources of mechanical energy include steam engines, water falling through a turbine or waterwheel, an internal combustion engine, a hand crank, a wind turbine, compressed air, solar energy, and many others. For hydro power generator, the mechanical energy from the water through the turbine is transmitted to the generator by shaft.

Electronic Load Controller: - is a controller that controls the frequency of the generated voltage in the micro-hydro systems.

Transformer: - is a device that transfers electrical energy from one circuit to another through inductively coupled conductors—the transformer's coils. A varying current in the first or *primary* winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic field through the *secondary* winding. This varying magnetic field induces a varying electromotive force (EMF), or "voltage", in the secondary winding. This effect is called mutual induction. If a load is connected to the secondary, an electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load. In an ideal transformer, the induced voltage in the secondary winding (V_S) is in proportion to the primary voltage (V_p), and is given by the ratio of the number of turns in the secondary (N_s) to the number of turns in the primary (N_p) as follows:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \tag{3.1}$$

By appropriate selection of the ratio of turns, a transformer thus allows an alternating current (AC) voltage to be "stepped up" by making N_s greater than N_p, or "stepped down" by making N_s less than N_p.

Transmission system:- is a system that interconnects generators and loads and generally provides multiple paths among them. Multiple paths increase system reliability because the failure of one line does not cause a system failure. Most transmission lines operate with three-phase alternating current.

Distribution system: - is the system that carries energy from the local substation to individual households, using both overhead and underground lines.

CHAPTER FOUR

SITE DESCRIPTION, DATA COLLECTION AND LOAD CALCULATION

4.1. Site Description

Temie River is located on east Gojjam Zone hullet Ejju Enesie Woreda 2km from keranio town. The river has a total length of 35.5km, a total catchments area of 119km^2. The hydro energy potential of Temie River is 14.3MW, where as in actuality case, currently the potential is lower due to the utilization of the water for irrigation purpose by the population. Its designed water head is 76 meters high, its diverted discharge is 0.212m3/s. The river crosses two Kebelles these are shigie and hizbe selam. shigie kebelle have 3377 male and 2905 female a total of 6282 people, and 1396 households. Hizbeselam kebelle have 4793 male and 4443 female a total of 9236 people, and 2116 households. From these kebelles some of the villages have get access of electricity from central grid connection, where as Dombit and nib gasha saint marry monastery have no access. So the thesis is focused on to electrify these villages. Dombit have 540 male and 459 female a total of 999 people and199 households. And also saint marry monastery have a total of 30 people and one church. Currently the communities are primarily using kerosene, candle and dry cells for lighting.

Figure 4.1: Picture of the Site (Temie River, Dombit, and Saint Marry Monastery)

As see from the above figure 4.1, temie river is crosses the two villages, Dombit and Saint Marry Monastery. Saint merry monastery is nearer to the river than Dombit so the transmission line expense for the Dombit village is greater than for the saint mary monastery. As much as possible the power house installation is proposed at the centre by taking in to consideration the place where better head is getting.

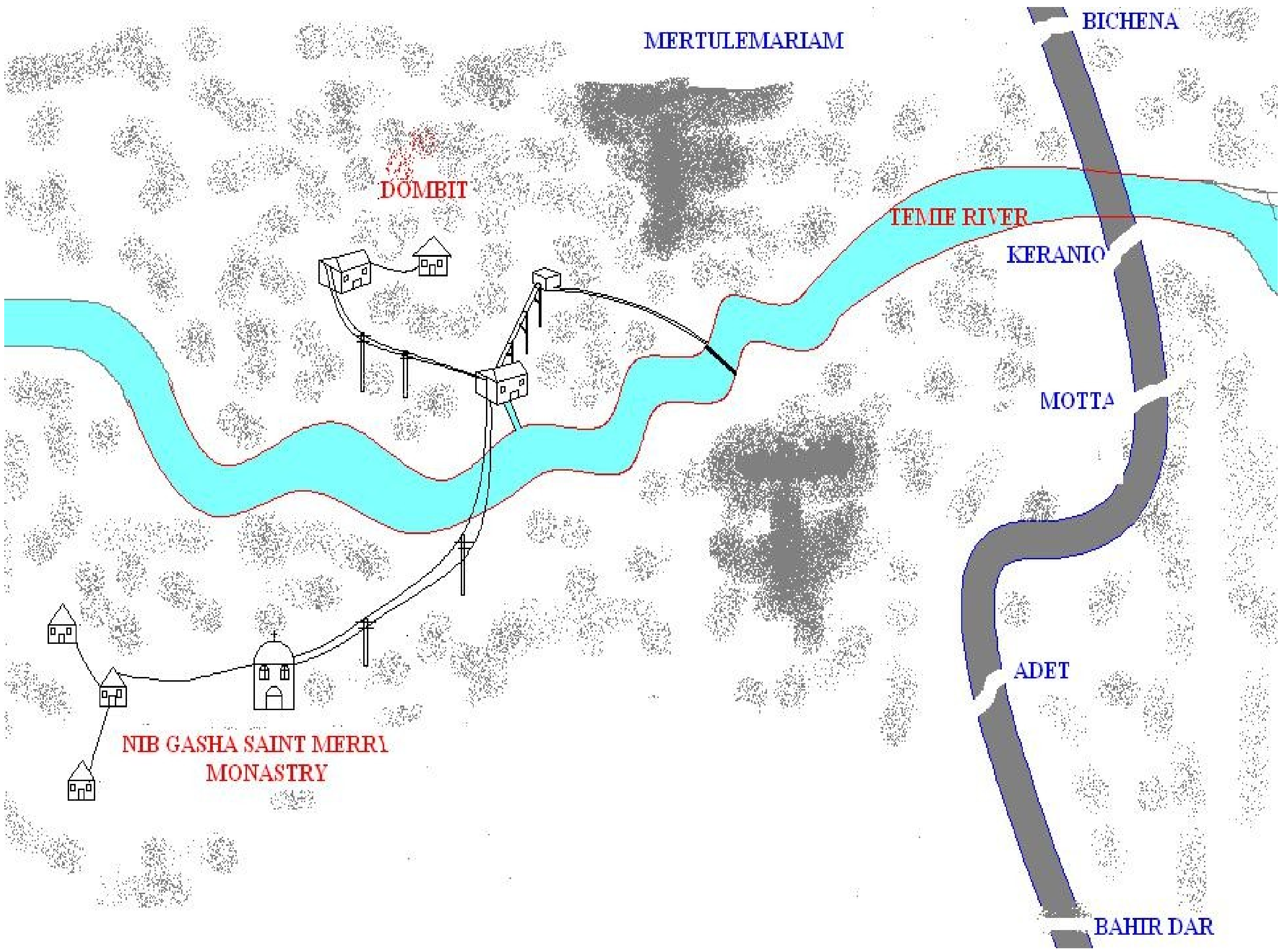

Figure 4.2: Lay Out of the Site (Temie River, Dombit, and Saint Marry Monastery)

As see from the figure 4.2 above, Temie river is crosses the main road that is from bahir dar to addis abeba through motta there fore it is cosy for the transportation system.

Figure 4.3: Picture of Temie River

As see from the figure 4.3 above, the topography of the site is irregular for the selection of power house installation area which is related to the discharge head, as much as possible select labeled area for the power house by takes in to account the designed discharge head.

4.2. Data collection

The design of micro hydropower system requires precise site information such as head, discharge rate (flow rate), and electrical information like load type and time of use electrical appliance. These requirements are going to be dealt here on this chapter in the subsequent section.

4.2.1. Determination of discharge rate

For a micro hydropower design it is very important to have flow data over as many years as possible to be sure how much water is available to run a turbine. These data give the designer the basic information for the selection of the turbine that works most efficiently. With this information and the demand of the consumers, the designer can choose the proper turbine and generator as well as he can define size and length of the grid for an isolated MHP.

Depending on the size of the river or stream there are different methods to measure the flow:-

1. Bucket methods

The bucket method is a simple way of measuring flow in very small streams. The entire flow is diverted into a bucket or barrel and the time for the container to fill is recorded. The flow rate is obtained simply by dividing the volume of the container by the filling time. Flows of up to 20 l/s can be measured using a 200-litre oil barrel.

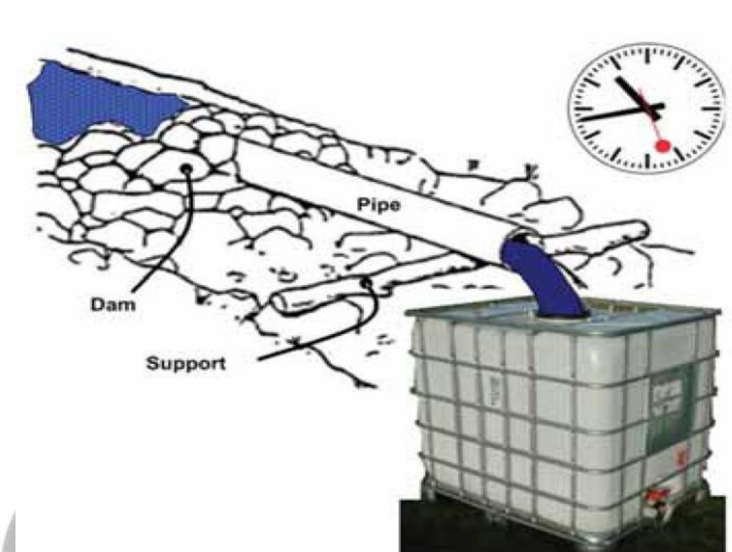

Figure 4.4: Discharge Measurement by Bucket Method [25]

2. Float method

The principle of all velocity-area methods is that flow Q equals the mean velocity V_{means} times cross-sectional A:

$$Q=A \times V_{mean} \quad 4.1$$

One way of using this principle is for the cross-sectional profile of a stream bed to be charted and an average cross-section established for a known length of stream. A series of floats, perhaps convenient pieces of wood, are then timed over a measured length of stream. Results are averaged and a flow velocity is obtained. This velocity must then be reduced by a correction factor which estimates the mean velocity as opposed to the surface velocity. By multiplying averaged and corrected flow velocity, the volume flow rate can be estimated.

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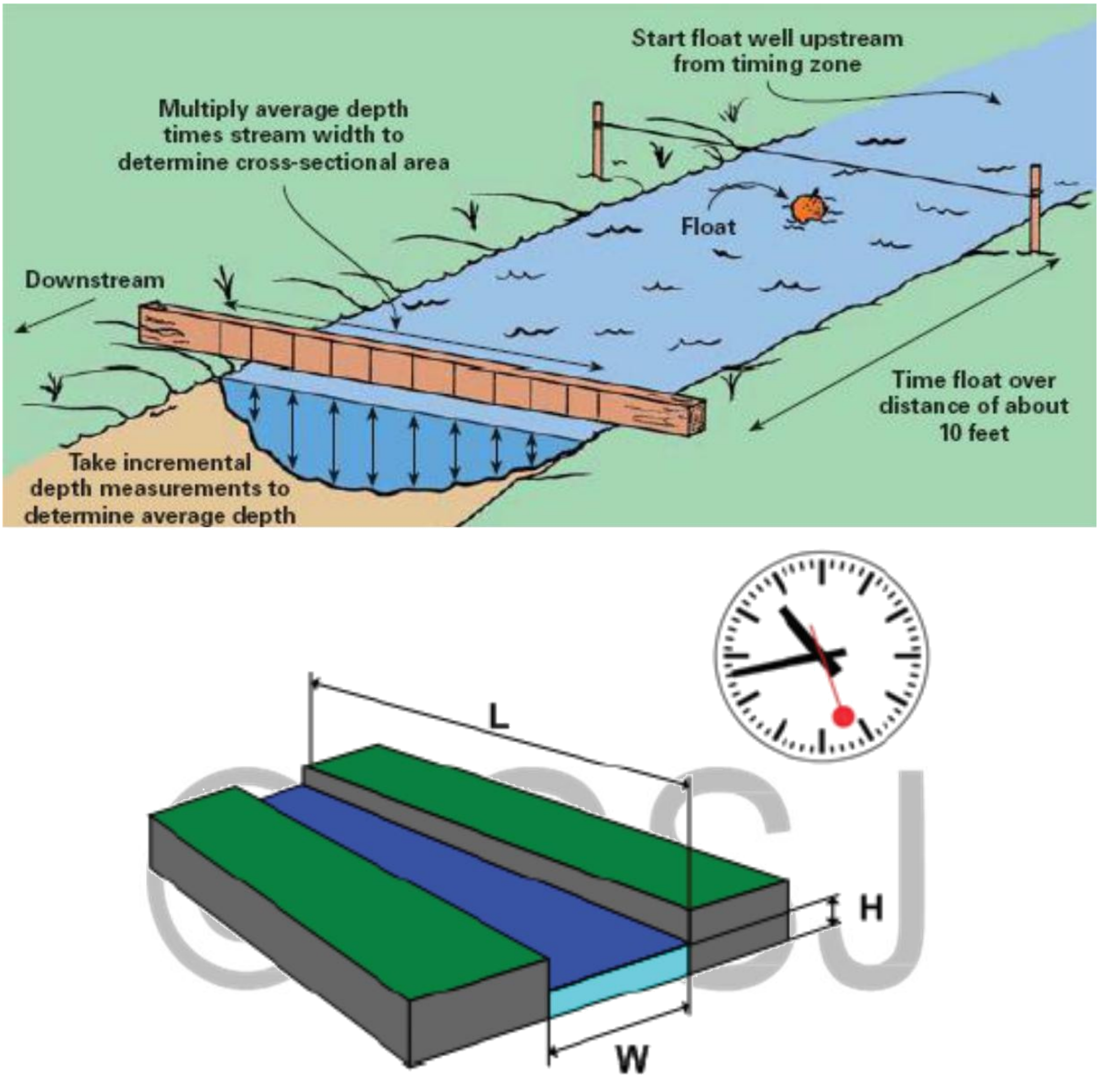

Figure 4.5: Discharge Measurement by Float Method [25]

3. Current meters

These consist of a shaft with a propeller or revolving cups connected to the end. The propeller is free to rotate and the speed of rotation is related to the stream velocity. A simple mechanical counter records the number of revolutions of a propeller placed at a desired depth. By averaging readings taken evenly throughout the cross section, an average speed can be obtained which is more accurate than with the float method. This method is suitable for flow velocities ranging from 0.2 - 5 m/s and where you can safely wide the stream.

Figure 4.6: Discharge Measurement by Current Meters [25]

4. Measuring weirs

A flow measurement weir is a weir with a notch in it through which all the water in the stream flows. The flow rate can be determined from a single reading of the difference in height between the upstream water level and the bottom of the notch. For reliable results, the crest of the weir must be kept sharp and sediment must be prevented from accumulating behind the weir. Sharp and durable crests are normally formed from sheet metal, preferably brass or stainless steel, as these do not corrode. Weirs can be timber, concrete or metal and must always be oriented at right angles to the stream flow.

Sitting of the weir should be at a point where the stream is straight and free from eddies. Upstream, the distance between the point of measurement and the crest of the weir should be at least twice the maximum head to be measured. There should be no obstructions to flow near the notch and the weir must be perfectly sealed against leakage. Rectangular notch measuring weir Temporary measuring weirs are used for short-term or dry-seasoned measurements and are usually constructed from wood and staked into the bank and stream bed. Sealing problems may be solved by attaching a large sheet of plastic and laying it upstream of the weir held down with gravel or rocks. It is necessary to estimate the range of flows to be measured before designed the weir, to ensure that the chosen size of notch will be correct.

The use of permanent weirs may be a useful approach for small streams, but larger streams might better measured by staging.

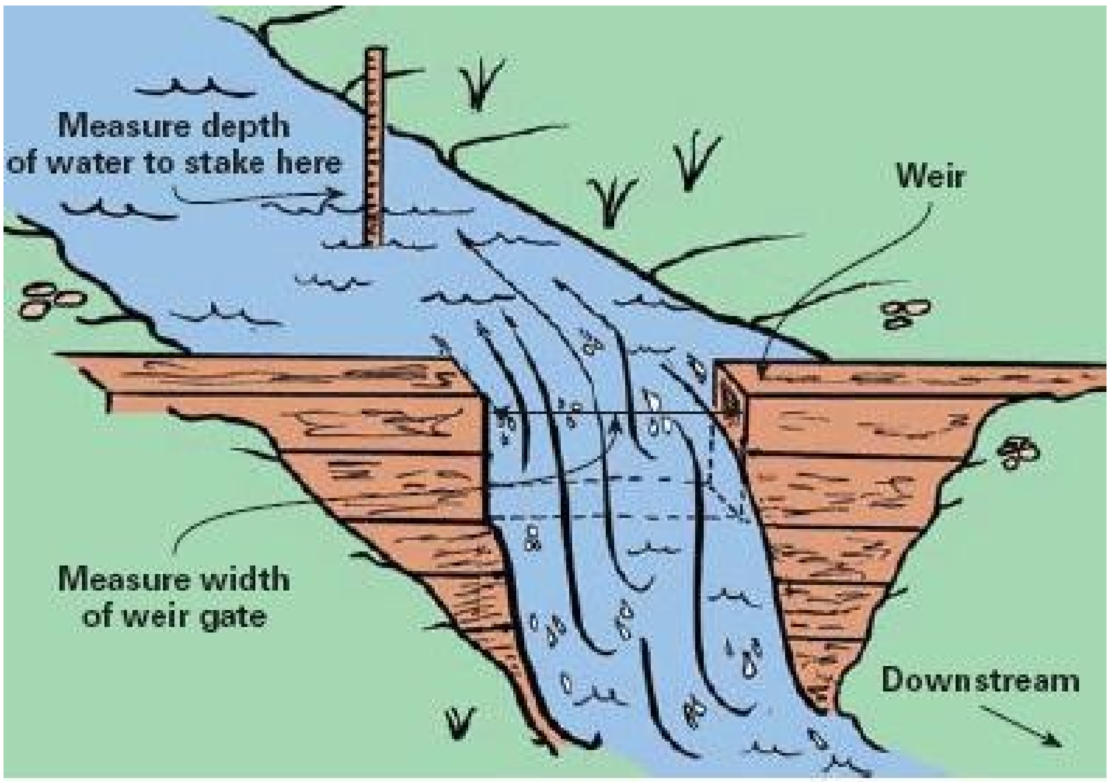

Figure 4.7: Discharge Measurement by Measuring Weirs [25]

5. Salt gulp' flow measurement

The `salt gulp' method of flow measurement is adapted from dilution gauging methods with radioactive tracers used for rivers. It has proved easy to accomplish, reasonably accurate (error <7 %), and reliable in a wide range of stream types. It gives better results the more turbulent the stream. Using this approach, a spot check of stream flow can be taken in less than 10 minutes with very little equipment.

A bucket of heavily salted water is poured into the stream. The cloud of salty water in the stream starts to spread out while travelling downstream. At a certain point downstream it will have filled the width of the stream. The cloud will have a leading part which is weak in salt, a middle part which is strong in salt and a lagging part which is weak again. The saltiness (salinity) of the water can be measured with an electrical conductivity meter. If the stream is small, it will not dilute the salt very much, so the electrical conductivity of the cloud (which is greater the saltier the water) will be high. Therefore low flows are indicated by high conductivity and vice versa. The flow rate is therefore inversely proportional to the degree of conductivity of the cloud.

The above argument assumes that the cloud passes the probe in the same time in each case. But the slower the flow, the longer the cloud takes to pass the probe. Thus flow is also inversely proportional to the cloud-passing time. Detailed mathematics will not be covered here because the conductivity metre is usually supplied with detailed instructions. The equipment needed for `salt gulp' flow measurement is:

- a bucket,
- pure table salt,
- a thermometer (range 0 - 40° C),
- a conductivity meter (range 0-1000 mS),
- An electrical integrator (Optional).

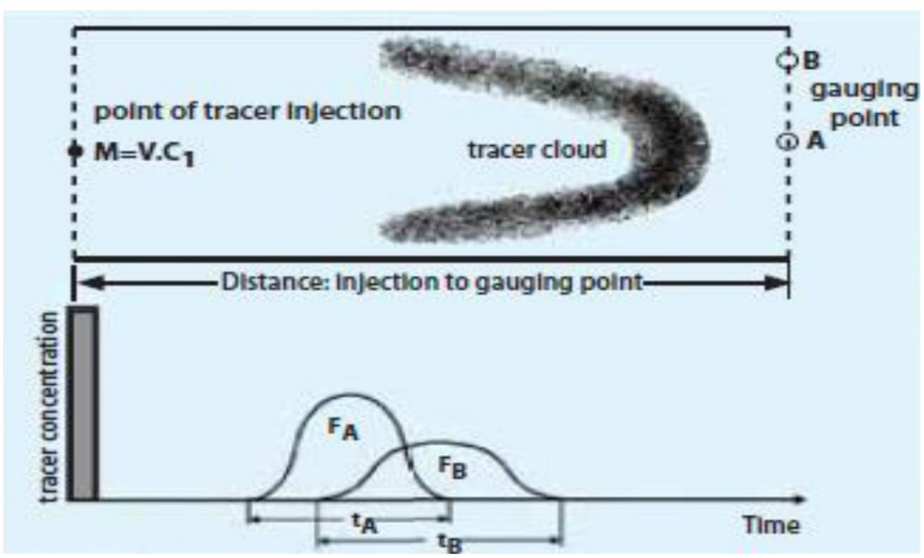

Figure 4.8: Salt Gulp' Flow Measurement [25]

4.2.2. Determination of head

Head measurements play an important role in determination of hydroelectric system parameters such as hydro turbine selection, system efficiency and hydrodynamic issues. For example; Kaplan, Cross-flow, Francis or Pelton turbines, hydrodynamics of turbine runner blade or bucket design, penstock material and strength, valve types, etc. are all impacted directly by the head measurement. All of these in turn impact the engineering and financial side of the micro hydropower system design.

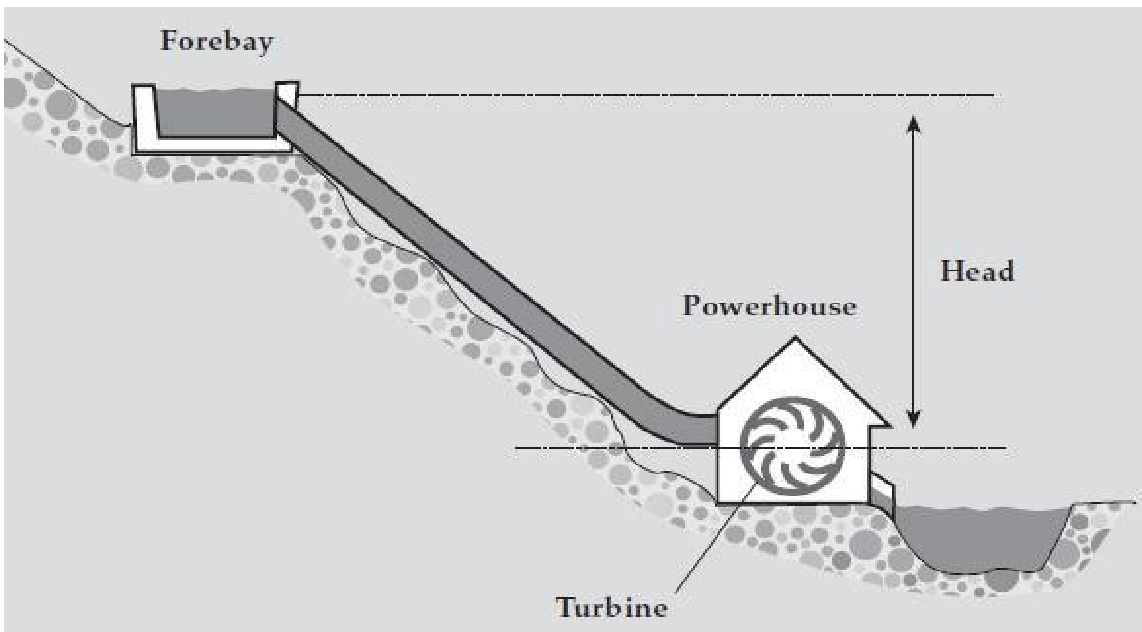

Figure 4.9: Head Lay Out [25]

There are three accurate hydropower head measurement methods, these are:-

1. **Surveyor's Transit or Levels and a pole**

This method uses a Surveyor's transit or contractor's levels and a marked pole. You can use 6.1 meter section of PVC (Polyvinyl chloride) pipe marked with a measuring tape attached for easier reading. The transit can be replaced by a straight board and level for economy, watch out for hydro head error buildup with short segments or warped boards or bad leveling though.

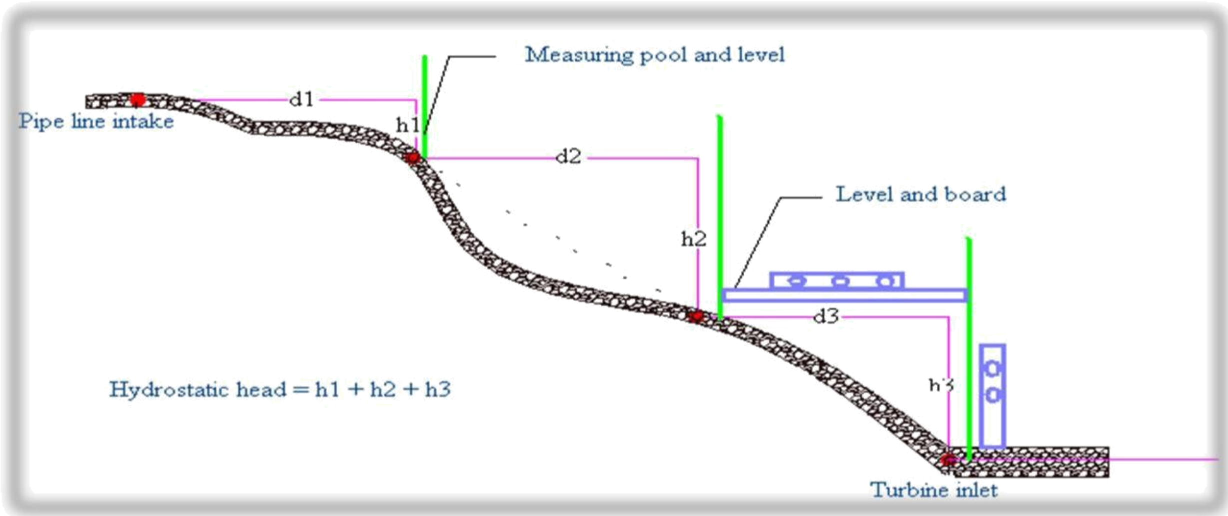

Figure 4.10: Surveyor's Transit or Levels and a Pole Head Measurement

1. Surveyor's Transit or Levels and a pole

By measuring the pressure in the hose, you can calculate the elevation change of your system. This method relies on the constant that each *vertical* foot of HEAD creates 0.433 psi of water pressure. (100 vertical feet would create 43.3 psi.). Allow the gauge pressure transients to settle to a stable reading. Multiply by 2.31 that will give you feet of head, if the distance is short enough, you can use one or more garden hoses to measure Head.

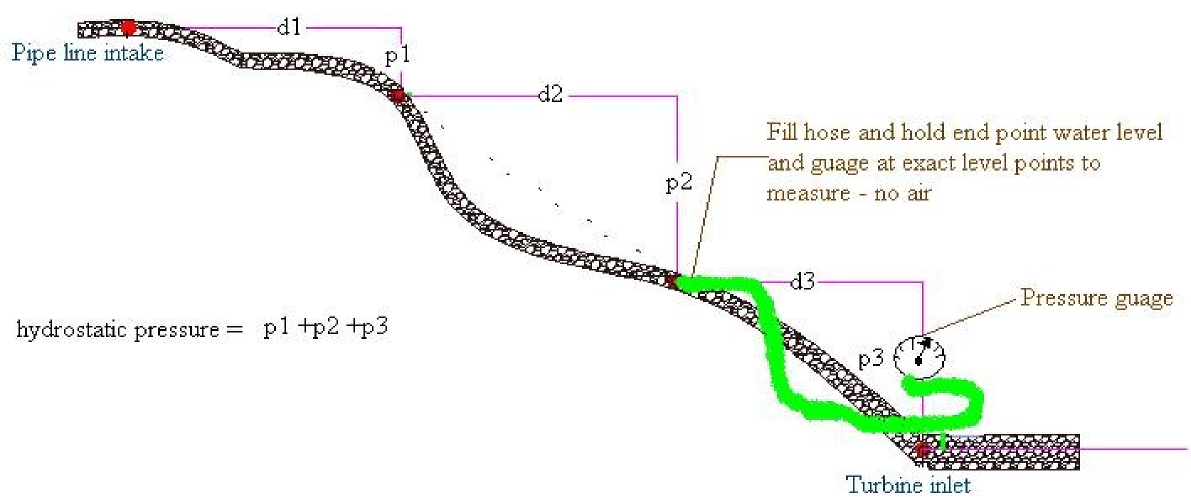

Figure 4.11: Measure Hydro Head with a Pressure Gauge & Hose

The formula is = A psi x 2.31 ft/psi = B feet of head or in meter, A psi x 0.704 m/psi = B Meters

2. Using a Precision Zip-Level Pro 2000™

This method is unique to DoradoVista's approach to hydropower head measurement. We will also show how to use it for accurate flow measurement in a later post about flow measurement methods. It is a very accurate differential pressure based geotechnical instrument. It is extremely accurate when used according to the instructions given by Technidea the manufacturer. The tool is also known as the Stanley Tools CompuLevel™ . This great instrument saves time, labor (one person operation is easy.) The Zip-Level is the most accurate method we know of for obtaining an easy and accurate measure of hydro head at a decentprice.

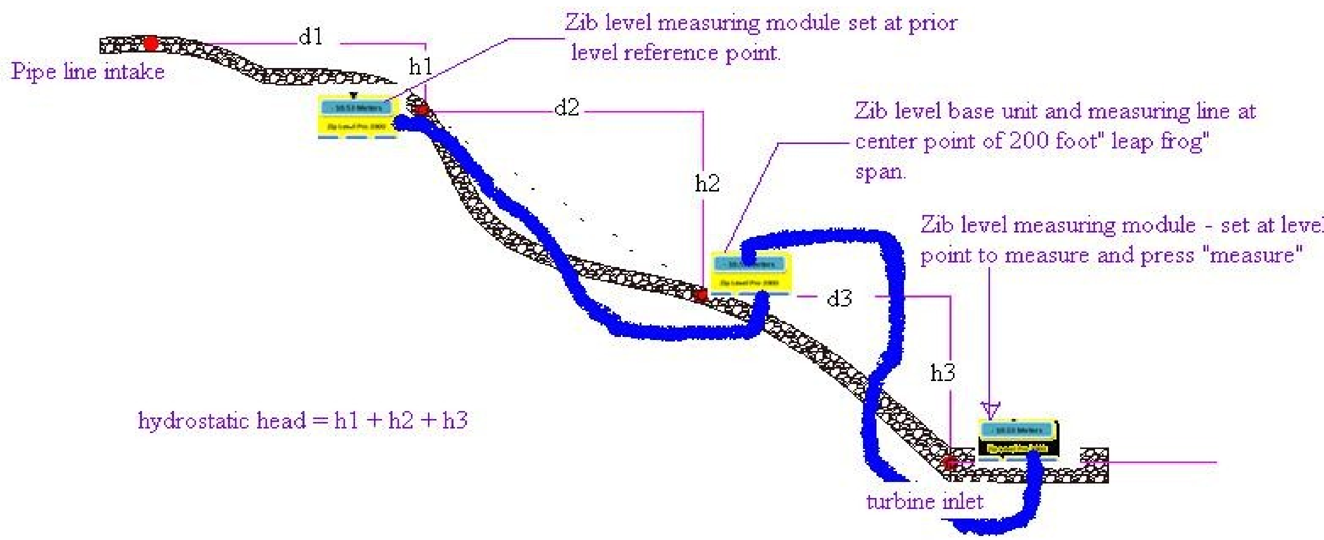

Figure 4.12: Head Measurement by Using a Zip Level Pro 2000™

4.3. Load Calculation

Once it has been estimated the hydropower data of the given site, in the next step it will be attempted to estimate the electrical load demand of the community which is the most significant steps in the design of a hydro power system. In the current study, Dombit which have 995 people (199 households) and nib gasha saint marry monastery which have 30 people (30 households) village community, are considered. A community school and religious institutions are also provided for the community. The load is of two types, a primary load, i.e., a load that must be met immediately, and a secondary load, i.e., a load that must be met within a certain time frame (although the exact timing is not important). The future load demand of the community may increase due to the rise the inhabitants in the village and additional requirement of power to use other electrical appliances.

4.3.1. Primary Load

Primary load is electrical demand that the power system must meet at a specific time. Electrical demands associated with lights, radio, TV and mobile charger are primary load as per the community requirement. When a consumer switches on a light, the power system must supply electricity to that light immediately the load cannot be deferred until later.

4.3.2. Deferrable Load

Deferrable load is electrical demand that can be met anytime within a defined time interval. Water pump, mill are an example of deferrable load because the storage inherent to each of those loads allows some flexibility as to when the system can serve them. The ability to defer serving a load is often advantageous for systems comprising intermittent renewable power sources, because it reduces the need for precise control of the timing of power production. If the renewable power supply ever exceeds the primary load, the surplus can serve the deferrable load rather than going to waste.

Calculation of Primary and Deferrable loads

Based on the Information obtained from different worker of the villages discussions held, and a further quantitative survey conducted in the villages transpired that currently the communities are primarily using kerosene for lighting, and dry cells. All households and institution establishments maximum require lighting for 5 hours per day. Currently this is being met primarily with kerosene, candle and dry cells. Based on information obtained, the quantitative non-cooking energy usage and expenditure pattern assessment survey, the energy needs of rural households and commercial establishments is characterized as follows. This has been done as per the two villages' community requirement.

Deferrable electrical load calculation

The deferrable load includes water pumps two in number for the monastery, eight for the Dombit village. Each pump with a 150W power rating on bases of the maximum head on site and a pumping capacity of 10 lit/min. These are able to pump 19900 lit/day for the 199 families (100 liters per family) and 3000 lit/day for the monastery. The deferrable load calculation for the total households of the Dombit village and the monastery is given bellow. The water pumps operate 5 hour per day.

$$E = N\times P\times h \qquad 4.2$$

E1 = 8×150W×5hr = 6000Wh = 6.0kWh (for the village)

E2 = 2×150W×5hr = 1500Wh = 1.5kWh (for the monastery)

Therefore the total electrical energy requirement is:

E_{total} = E1 + E2 = 6.0kWh + 1.5kWh = 7.5 kWh

Primary electrical load calculation

Primary load is electrical demands associated with lights, radio, and TV as per the community requirement. Concerning about lighting, there are three different types of lamps options such as incandescent, fluorescent/compact fluorescent and light emitting diode (LED). Here it has been selected compact fluorescent lamp which is superior efficiency and longevity compared to an incandescent lamp. It consumes quarter of the energy compared to an incandescent lamp. In addition these bulbs generally work in either alternating or direct current system though the weight must much the system's nominal voltage and current type. Comparison compact fluorescent and incandescent between is given in table 4.1 bellow.

Table 4.1: Comparison between Compact Fluorescent and Incandescent Lamps

Comparison criteria	Compact fluorescent	Incandescent
image		
Energy Input (watts)	14	60
Light Output (lumens)	810	830
Useful life (hours)	10,000	1500
No. of bulbs	1	6.7

The type and power rating of the electric appliances that are going to be used by the community is given on the following table so that it enable to estimate all the power required by the village and monastery in the site.

Table 4.2: Typical Wattage Requirements for Electric Appliance

Types of electric appliance	Power ratting in Watt
Compact fluorescent	14
Radio receiver/Caste player	15
14‖ color television	50
Libratory equipment	5184.15

The energy demand requirement of the households in the given village is different depend on their current economic status. Therefore, the community is classified in to three categories according to their energy demand.

The maximum power of primary load per household in the Dombit village is nearly to be 121 W (15W radio receiver/Caste player, four 14W light bulbs and 50 W 14'' color Television). The total daily energy consumption of the families is 63,985Wh, if they are using 5 hours per day. And total daily energy consumption institutions of the model Keble is depicted in table 4.2.

Table 4.3: Household Energy Demand Size of Dombit Village.

Electrical Appliances	No. of	Use Hour per day	System size [Watt]	Daily power use of household[Wh/day]
2bulb + Radio\ Caste player	79	5hr	43	16,985
3bulb + Radio \Caste player	80	5hr	57	22,800
4bulb + Radio\ Caste player+14" color TV	40	5hr	121	24,200
Total	199	15	221	63,985

Table 4.4: Monastery and Dombit Institution Daily Energy Demand

Institutions	Electrical Appliances	Watt	Use hours per day	Daily energy use(Wh/day)
Monastery households	40bulbs	560	8	4,480
Monastery church	6bulbs	84	8	672
Dombit church	6bulbs	84	8	672
Dombit school	12 bulb +14" color TV	218	7	1,526
	10 bulbs	140	16	2240
Dombit health Center(Clinic)	14" color TV	50	24	1200
	Libratory equipment	5184.15	8	41473.2
Total		6320.15	79	52263

Since the deferrable and primary load energy requirement once it estimated individually, the next step is to estimate the total daily energy consumption for all of cosumptions. The total daily energy consumption is therefore the sum of power consumption household of the monastery and Dombit village, school and church, plus the deferrable load, which adds up to 78.7kWh.

$E_{totaldaily} = E_{diff} + E_{Do} + E_{in}$ 4.3

But, E_{diff} = 7.5kWh E_{Do} = 63,985kWh E_{in}= 52.263kWh

$E_{totaldaily}$ = 7.5kWh +63,985kWh + 52.263kWh = **123.748kWh/day**

Peak Load

Interest of the people to use the appliance is vary with time and demand type, but the maximum requirement of the hydropower system will exist when all the appliances are turn ON at the same time and this load is called the peak load of the system. The peak load can be found by dividing the total daily demand of the site with the operating hour of the appliances, i.e.

$$\text{Peak load(kw)} = \text{(electricity Demand(kwh))} \big/ \text{(hour of operation)} \tag{4.4}$$

$$\text{Peak load(kw)} = 123.748\text{kWh} \big/ 5\text{hour}$$

$$= 24.75\text{kW}$$

And also there is additional appliance for the site i.e. grain mills (flour mills). For the case of this thesis one machine for the Dombit and another machine for the monastery. A total of two grain mills machine is applied. Each machine is consuming 15kw power.

So the total peak load is 15 + 15 +24.75 =**54.75kW**

Load Factor

The load factor of an energy technology is the ratio (expressed as a percentage) of the net amount of electricity generated by a power plant to the net amount which it could have generated if it were operating at its net output capacity. For any type of power plant it is possible to calculate the probability of it not being able to supply the expected load. [16].

Table 4.5: Load Factor of Different Energy Technology, Source: [16]

Energy Technology	Load factor
Sewage Gas	90%
Farmyard Waste	90%
Energy Crops	85%
Landfill Gas	70-90%
Combined Cycle Gas Turbine (CCGT)	70-85%
Waste Combustion	60-90%
Coal	65-85%
Nuclear Power	65-85%
Hydro	40-60%
Wind Energy	25-40%
Wave Power	25%

The load factor of hydro power varies according to the site and the type of turbine, where as for this thesis takes the maximum i.e. 60%.

$$\text{Peak load(kw)} = 54.75/\ 0.6 \qquad 4.5$$

Therefore, the design load of the system is **91.25kW**

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CHAPTER FIVE

4.75

MICRO HYDRO POWER SYSTEM DESIGN ANALYSIS

5.1. Introduction

Once the all the input resources data have been estimated and analyzed, the next step to design and model the micro hydro power system. Micro hydro power systems can be designed using analytical methods and computer simulation based methods. Foremost, micro hydro power system model is attempted to design analytically and then followed by using simulation programs. The

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most popular simulation programs currently in use today are Ansys, CFD like Fluent, MATLAB, and Solid Work etc. But here, due to time limitation the work is done only by analytically.

Weir

Weir for hydropower needs detail design, but for micro type it works only to divert the flow, so detail design it may not be necessary. In this thesis intake and rectangular type of weir is selected and sized.

Weir Water way (L)

It is the width provided at the site for the river water to flow. In other word, it is the length of the weir. Approximate water way to provide between the abutments may be calculated from lacey's regime perimeter formula.

$$P_w = \times \sqrt{Q} \qquad 5.1$$

Where P_w – is the wetted perimeter at the site at the river, but in this case it denotes the length of the weir between the abutments in meter and denoted by L.

$$P_w = 4.75 \times \sqrt{0.424}$$

$$= 3.1$$

Q – The maximum design discharge in m^3/s

$$Q = C_w \, L \, H^{0.5} \qquad 5.2$$

For the Rectangular Weir without Contracted End

Where: Q = discharge, (m^3/s)

C_w = weir coefficient, 1.84

L = weir length, (m)

H = head above weir crest, (m)

$$H=\sqrt{((0.424)/1.84x3.1)} \qquad 5.3$$

H = **0.273meter**

Discharge intensity (q)

Discharge intensity (q) = (0.424m3/s)/3.1m = 0.137 5.4

Where

H-Total energy level above the crest of the weir

$$\mathbf{H} = (q/1.71)^{2/3} \qquad 5.5$$

= **0.186** meter

To get proper design take the maximum value i.e. 0.273

H =Hsd + ha 5.6

ha – velocity head.

Hs_d – water head above the crest of the weir

Normal scour depth (R)

$$R = 1.35x(q/f)^{1/3} \qquad 5.7$$

Where q – discharge intensity.

f – Silt factor for standard silt 1.5

R – Scour depth

Then

R = 0.61meter

Regime velocity

Under the flood condition when the weir expected to attain regime condition

Regime velocity $V = q/R$ 5.8

Where R – scour depth

V= 0.225m/s

Approach velocity head, $ha = V^2/2g$ 5.9

ha = 0.00257

Thus water head above the crest of the weir.

Hsd = H – ha 5.10

= 0.273 - 0.00257 = **0.27m**

Channel

There are many different shapes of channel that flow occurs in and it is often necessary to estimate the flow rate in the channel for engineering purposes, such as for designing concrete drainage channels to handle the flow of storm water. Different channel types include:

- Flow in Part full pipes.
- Flow in Part full rectangular sections.
- Flow in Rectangular channels.
- Flow in Flat bottomed channels (with sloping sides).
- Flow in V shape channels.

The size of the channel cross-section should be obtained from design drawings or measured in the field. From this different type of channel due to its simplicity for construction select the rectangular type for this work.

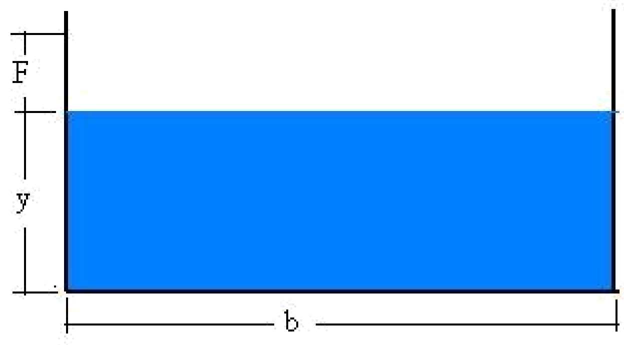

Figure 5.1: Rectangular Channel

$Q = VA$ 5.11

A = Flow cross-sectional area [m^2]

V = Average velocity of the water [m/s] according to K.N Sharmas (water power eng)

Q = Discharge or flow rate [m^3/s]

V = k/n R^ (2/3) S^ (1/2) 5.12

$R = A/P$ 5.13

$A = by = y^2$ 5.14

$P = 2y + b = 3y$ 5.15

b = Channel bottom width [m]

y = Water depth [m]

P = Wetted perimeter [m]

k = unit conversion factor = 1

n = Manning coefficient (n = 0.014, see Appendix-J)

R = Hydraulic radius of the flow cross-section (m).

S = Slope of channel bottom or water surface [m/m]. Vertical distance divided by horizontal distance or is the slope of the water surface or the linear hydraulic head loss (S = 0.8, see Appendix-J).

By substitute these values on the above equation, By substitute these values on the above equation,

Y = **0.833** meter

$$F = \sqrt{CY} \tag{5.16}$$

F = free board length in meter

C = freeboard coefficient = 0.0089

By substitute these values on the above equation,

F = **0.273**meter

Penstock

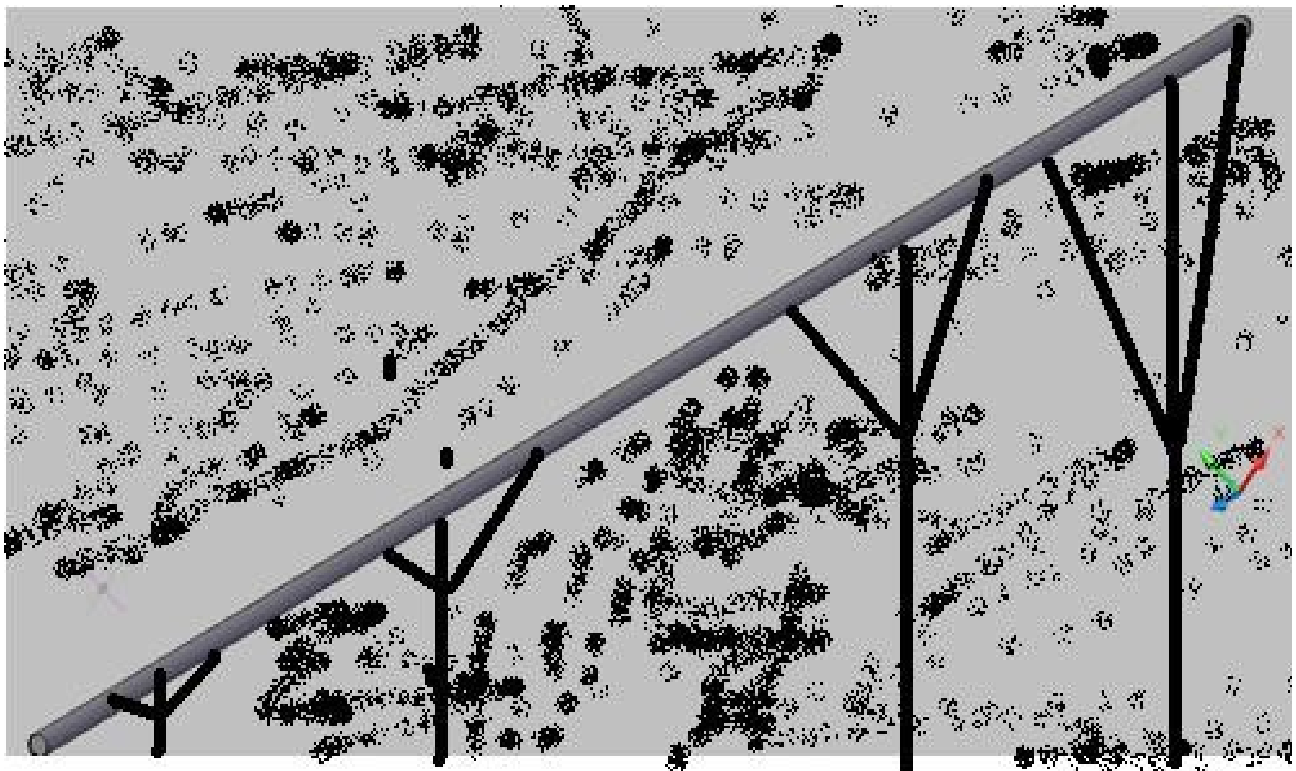

Figure 5.5: Alignment of Penstock

Penstock diameter

Good penstock diameter depends on three factors:

- Energy (head) losses due to friction between the water flowing in the pipe and the inside pipe wall
- Pressure limitations of the pipe as a function of wall
- thickness Cost of the pipe and installation

For a given flow rate, as the pipe diameter decreases the velocity of the water must increase, and the corresponding energy loss increases. This occurs because friction is a function of velocity. As velocity increases, friction increases. On the other hand, a larger pipe diameter would mean a decrease in velocity and a corresponding decrease in friction (head loss). The cost of the pipe however, increases drastically with the increase in size. The procedure presented here will help you balance energy loss with pipe size, material, and wall thickness. The energy losses associated with friction can be expressed directly as meters of head loss. Friction losses in the penstock system symbolize energy that is not available for power generation.

Sizing the proper penstock diameter is done by:-

1. reading from the graph
2. analytically

Reading from the graph

To read from the graph first calculate the optimum velocity of the flow through the pipe by using USBR Formula i.e.

$$V = C^* \sqrt{2gh} \qquad 5.17$$

Where

C = penstock roughness constant

V = optimum velocity in m/s

G = gravitational acceleration

H = maximum height

Therefore

V **=** 0.0625 X $\sqrt{2gh}$

= **2.4m/s**

= **7.9 f/s**

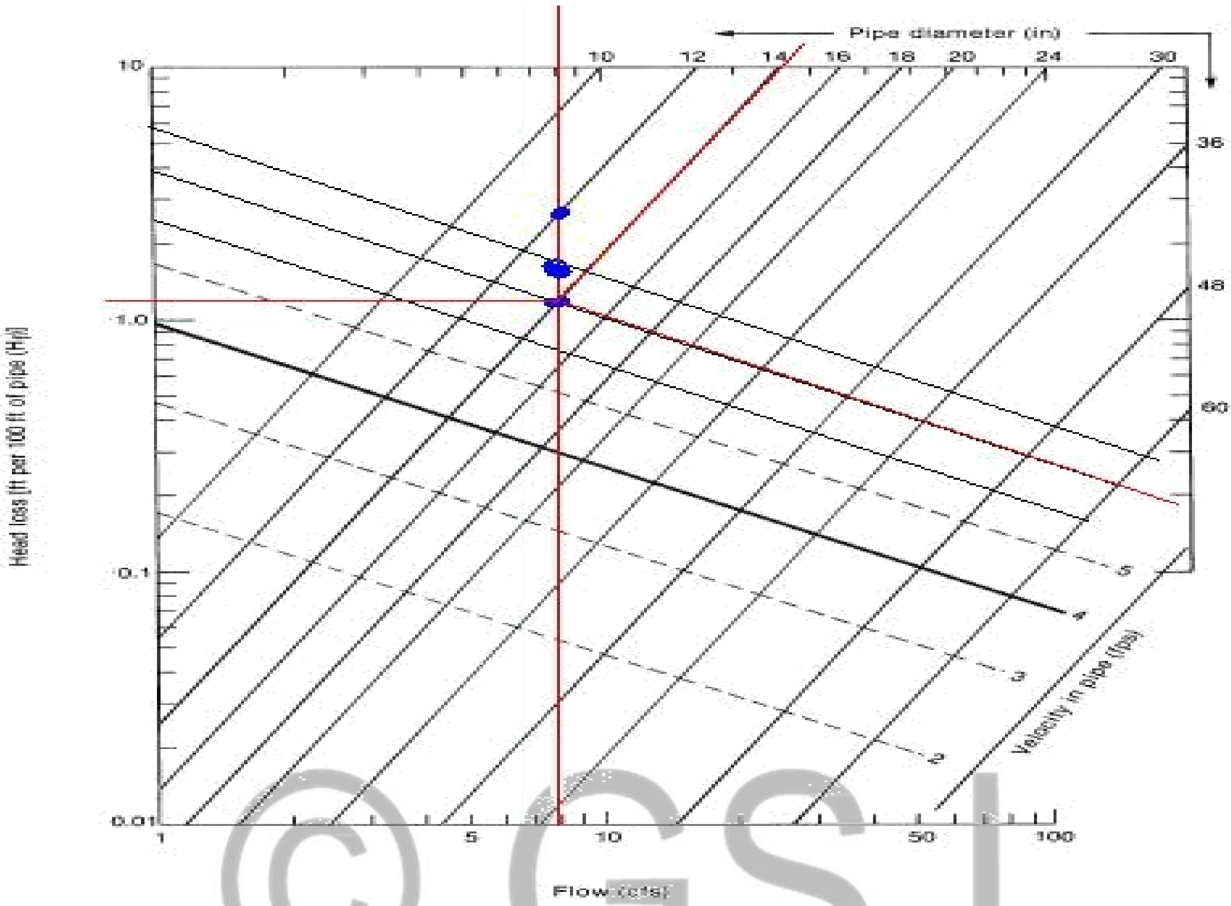

Figure 5.7: Penstock Diameter Selection Graphs [27]

From the graph, the diameter is 14 inch **= 1.17 foot = 0.356 meter**

Analytically

The empirical equations to compute the economical penstock diameter is: -

1. **Ludin – Bundschu** empirical equations depending on the head

[14] If H_{gross} < 100m, use the formula,

$$D = \sqrt[7]{0.05Q^3} \qquad 5.18$$

If H_{gross} >100m, use the formula,

$$D = \sqrt[7]{(5.2Q^3)/Hgross} \qquad 5.19$$

Where H_{gross} is the gross head from the forebay to the turbine

Q is the total discharge

D is penstock diameter

For this work case Hgross = 76 meter i.e. less than 100, so

$$D = \sqrt[7]{0.05X0.212^3}$$

= **0.3353 meter**

2. **Sakaria empirical equation** [15]

$$D = 0.71 \times P^{0.43} / H^{0.65} \qquad 5.20$$

Where

D → penstock diameter

H_n → The net head from the forebay to the turbine = 75.5

P →rated capacity of turbine (theoretical power output) = 126.44 D =

0.342 meter

Penstock thicknesses

To determine the wall thickness of penstock under normal flow penstock subjected to only internal hydrostatic pressure. But when gates at the end of penstock closed suddenly there will be water hammer phenomena. So the thickness provides has to be sufficient enough to resist both water hammer and hydrostatic pressure.

Linear Thickness $t = 2pxD \ /\sigma$ 5.21

Where: -

P _ maximum penstock pressure multiplied by a factor about 2 (for water hammer prevention) = 152.91

t _ penstock thickness

D _ Diameter of pressure shaft or penstock =0.36

_ Allowable stress =1600

There fore

t = 2x152.91x0.36/1600

= 17mm

Additional thickness for protection of corrosion is provided around

1.5mm Total thickness = **18.5mm**

Penstock Materials

The turbine manufacturer may have recommended a certain material for the penstock. You may want to consider other material that might be less expensive. The most common penstock materials include:

- PVC (polyvinyl chloride)
- Steel
- Polyethylene
- FRE (fiber reinforced epoxy)
- Transite (asbestos cement).

To select penstock material, **f**or each of these materials, you must consider a number of factors:

- Cost
- Availability
- Physical properties
- Joining methods and installation limitations.

The selection of penstock material and penstock wall thickness highly depends on the pressure that the pipe will experience. There are two types of pressure to be considered:

Static pressure, which is the pressure at the bottom of the pipe when the pipe is filled and the water, is not flowing.

Pressure waves, which are caused when the amount of water flowing is suddenly changed, as by opening or closing a valve.

Static pressure depends on the head in the penstock. Pressure waves depend on how fast the flow changes in the penstock.

To aid in determining the design pressure rating of the penstock and selecting the suitable pipe material, Appendix-J lists the wall thickness(t)' pressure rating CPR)' and surge allowance factor (SA) for pipe materials.

The static pressure in the penstock at the turbine can be determined

1. by using the Equation

$$S = 0.433 \times h \quad 5.22$$

Where

S = static pressure

h = design head.

There fore

S = 0.433x76

= **32.91**

2. Using the penstock diameter previously established, select from Appendix-J one or more potential pipe materials and select the t_w, P_R, and S_A factors for these materials.

3. For each pipe material selected, use Equation5.21 to determine the penstock design pressure (P_d).

P_d = static pressure + pressure wave

$$P_d = S + (S_A * V) \quad 5.23$$

Where

P_d = penstock design pressure

S = static pressure

S_A = surge allowance factor

v = velocity of the water in the pipe

P_d = 32.91 + (50*2.4)

= 152.91N/m^2

Calculating Penstock System Head Loss

The total losses are a function of both turbulence and friction. Turbulence is caused by the intake structure and by bends and obstructions in the pipe. Turbulence factors can best be considered by adding equivalent pipe length to the overall length of the penstock to get the adjusted length (La). This can be done by the following steps:

Multiply the number of 90 degree bends by 9.2 meter, Multiply the number of 45 degree bends by 4.6 meter, Add 4.6 meter for the entrance at the intake, Sum all the additions and add to the total penstock length.

For this work the penstock length is 88 meter, and there is no bend, the pipe is installing straight with supporter. So the adjusting length is:-

La = 88 + 4.6 = 92.6 meter 5.24

Friction losses are a function of pipe size, length, and material. The friction effect is accounted for with the pipe material correction factors shown in Table 5.2.

Table 5.1: Friction Loss Correction Factor (Fc) [27]

Pipe Material	Factor(f_c)
Steel	1.16
PVC	0.77
PE	0.77
AC	0.87
FRP	0.77

To obtain the head loss due to turbulence and friction, multiply the adjusted penstock length (La) determined above by the material correction factor from Table 5-2. Multiply this number by the H_f factor previously determined from Figure 5.7 and divides the result by 100. This final number is the energy loss, in feet of head, for the flow, penstock length, and material selected. Use Equation 5.26 to determine total head loss. L_a

$$H1 = (fcxLaxhf)/100 \quad (5.25)$$

Where

H1= head loss in meter

fc = friction loss correction

La= adjusted length of penstock in meter

hf = head loss factor from

$$H1 = (0.77X92.6X\ 0.3353)/100$$

$$= 0.24 \textbf{ meter}$$

So the net head is = 76 – 0.24 **= 75.7 meter**

Turbine

From the electromechanical parts, turbine is the core of the plant in a sense that the final hydropower output is highly depend on the performance of the turbine. Before design analytically Selection of turbine based on the site data is the prior work. Which type of water turbine is best for a particular situation often depends on the amount of head (water pressure) you will have in your site and whether you want to suspend the turbine in the water (reaction) or whether you want to use jets of water (impulse). By looking at these factors together you can get some indication of what type of turbine design will work best:

Selection of Turbine

There are numerous parameters for selection of turbine .The usual practice is based on:

- Technical and economical considerations
- Operating head and power output
- Specific speed.
- Efficiency

Specific speed

Specific speed is the speed in revolution per minute at which the runner would run, if reduced in size to deliver one gallon per minute against a total head of one foot. Runner for high heads usually has low specific speed and runner for low head usually have high specific speed. Specific speed is a useful parameter of turbine for a given condition and it is expressed as:

$$N_S = \frac{N\sqrt{P}}{H^{5/4}} \qquad 5.26$$

Where: N_S = specific speed

N= rotational speed (rpm)

P = power developed (kW)

H = effective head (m)

For the selected site area the specific speed is:-

$$N_S = 1500\sqrt{91.25}/75.7^{\wedge}(5/4)$$

$= 64.2$rpm

Efficiency:

A significant factor in the comparison of different turbine types is their relative efficiencies both at their design point and at reduced flows. Typical efficiency curves are shown in the figure below.

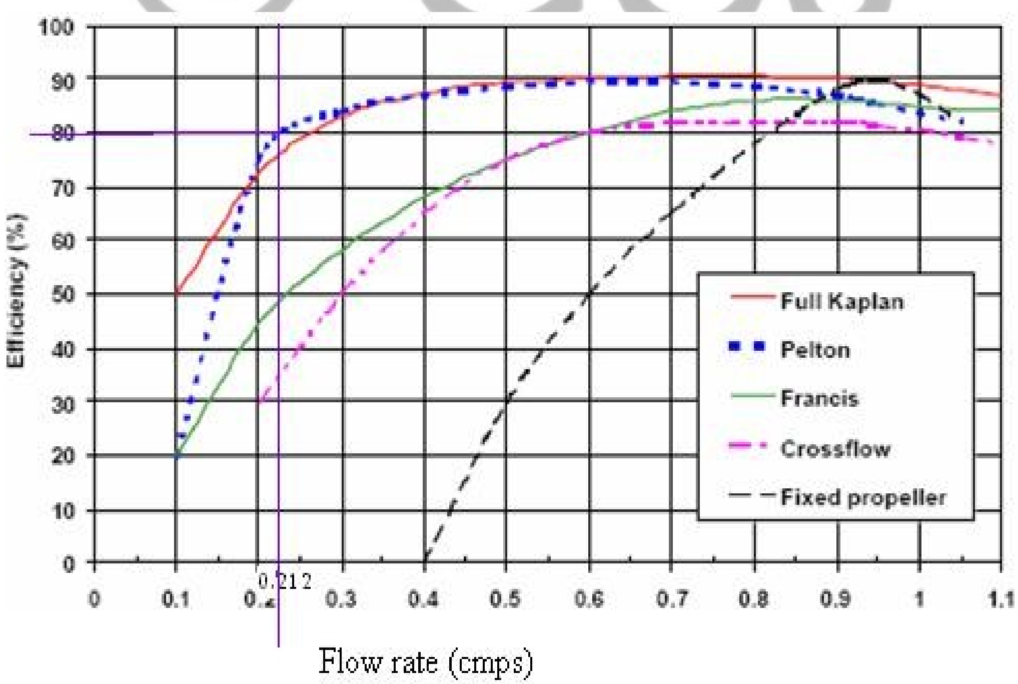

Figure 5.1: Efficiency of Various Turbines Based On Discharge Rate [19]

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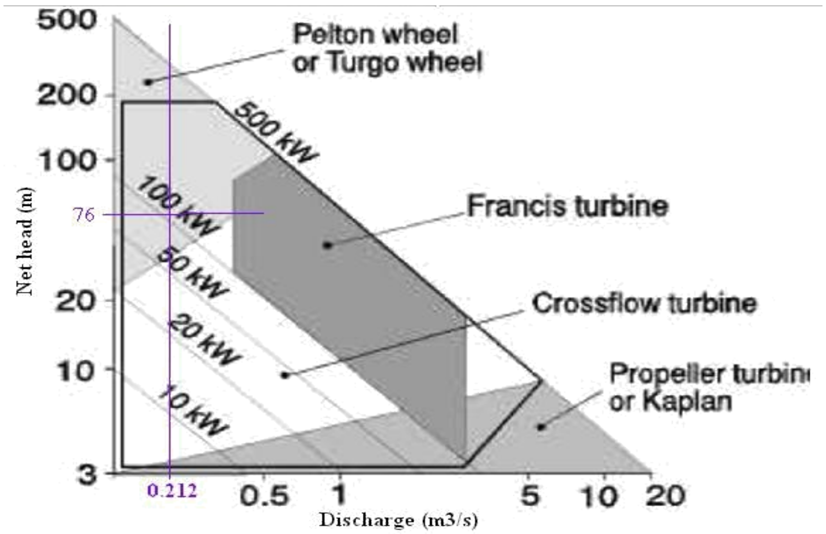

Figure5.2: Turbine Selection Based On Head and Discharge [19]

Based on the above figure and efficiency graph and also economical consideration and specific speed for the micro hydropower to electrify rural area that far from the central grid connection for the selected site and the desired energy demand, penton turbine is best.

Design of penton turbine

Pelton turbine consists of three basic components as shown in Figure 5.3 a stationary inlet nozzle, a runner and a casing. The runner consists of multiple buckets mounted on a-rotating wheel. The jet strikes the buckets and imparts momentum. The buckets are shaped in a manner to divide the flow in half and turn its relative velocity vector nearly 180°. The primary feature of the impulse turbine is the power production as the jet is deflected by the moving buckets. Assuming that the speed of the exiting jet is zero (all of the kinetic energy of the jet is expended in driving the buckets), negligible head loss at the nozzle and at the impact with the buckets (the entire available head is converted into jet velocity).

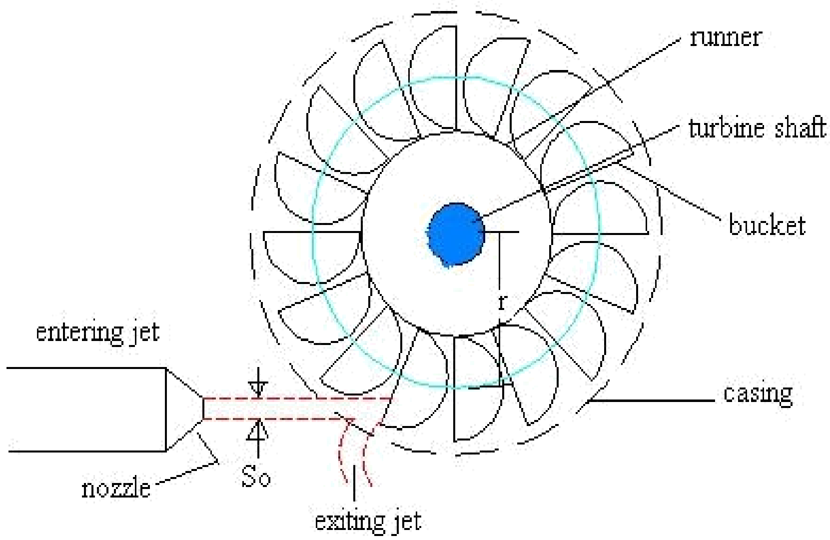

Figure 5.3: Schematic of an Impulse Turbine

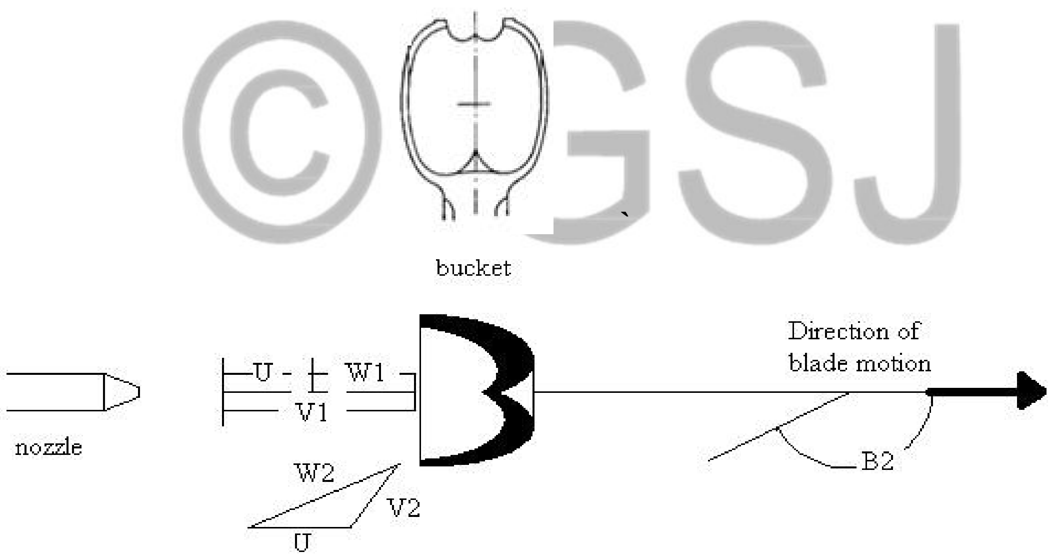

Figure 5.4: Velocity Diagram of an Impulse Turbine

Where V = absolute (water jet) velocity

U = tangential velocity

W = relative velocity

For Pelton turbine, U1 = U2 = U

Site data

According to the head, can be classified in three categories: High head 100m and above Medium head 30 – 100m Low head 2 – 30m

The site under consideration in the present work is a head of 76m and can be categorized high head site. The volumetric flow rate available is 0.212m3/s.

Firm Power is the power that is always available from the stream, even at times of lowest flow and lowest head. To calculate firm power you use the lowest expected flow in the stream (Qmin) and the net head (Hn).

$$P = Q_{min} * g * Hg * \rho * \eta \qquad 5.27$$

Where:-

- P = power (J/s or watts)
- η = overall efficiency, = $\eta_t * \eta_g * \eta_t * \eta_l$
- $Q_{min}^{\cdot}$ = minimum flow rate (m^3/s)
- ρ = density of water (kg/m^3)
- g = acceleration of gravity (9.81 m/s^2)
- H_n = net head (m).

Therefore:

$P = 0.80*0.90*0.92*0.90*1000*75.7*9.81*0.212$

P = 93.86KW is the load that reached to the demand

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Calculation of Runner rpm

The turbine and the generator are fixed (directly connected with shaft). The rated speed of the turbine is the same as synchronous speed of the generator. The speed N for synchronous running is given by**:**

$$N = \frac{120\,f}{Np} \tag{5.28}$$

Where:

f = frequency of AC supply (50HZ)

Np = number of generator poles (4)

N = runner rpm

Then, N **= 1500rpm**

The speed of the turbine is an important parameter of design. The higher the speed, the smaller will be the diameter of the turbine there for decrease material cost. High speed, however, makes the turbine more disposed to cavitations. And also the lesser the speed gives the machine longer life because of lesser wear and tear but increase in material cost.

Calculation of Water Jet Velocity

The water jet velocity or the absolute velocity is calculated using the head of the site, the coefficient C accounts for the roughness in the water head i.e.

$$V1 = C\sqrt{2gH} \tag{5.29}$$

With H = 75.7m, g = 9.81m/s^2, C = 0.98

V1 = **37.77m/s**

Calculation of Runner Tangential Velocity

The maximum power is occur at V1 = 2U 5.30

U = 0.5x37.77

= 18.9m/s

Calculation of Runner (Turbine) Outer Diameter

$U = r\omega$ 5.31

$r = U/\omega$

$\Omega = 2\pi N/60 = 2x\pi x1500/60 = 26.2$ 5.32

Then, r = 66.6cm

D = 2r = **133.2cm** 5.33

Runner Inner Diameter

The suggested inner to outer diameter ratio for penton turbine is 0.7. [Aziz and Desai, 1991] Therefore;

Runner inner diameter = 0.7x133.2 5.34

= **93.24cm**

Radial rim width = (133.2-93.24)/2 5.35

= **19.98cm**

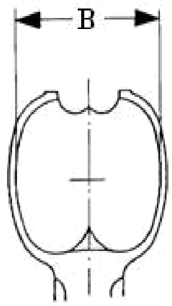
Thickness of Water Jet

$S_o = 0.2xD$ 5.36

= 0.2x133.2

= **26.6cm**

Width of Bucket



For one nozzle turbine:-

$$B = 3.1X\ So \quad 5.37$$

$$= 3.1x26.6$$
$$= 82.46cm$$

Turbine Alignement

The turbine-generator lay out can be either a horizontal shaft lay out or vertical shaft layout .In a horizontal shaft lay out, the turbine and the generator are at the same elevation connected by a horizontal shaft .On the other hand in vertical lay out the generator is on the top of the turbine, both connected by a vertical shaft .for this thesis work the horizontal arrangement is preferred due to The generator more weight than the turbine, therefore, vertical alignment is not fine for the turbine

Selection of Material

Carbon Steel Castings are commonly used for turbine. ASTM A216 castings are of slightly higher strength than the more commonly used ASTM A27 material. ASTM A216 material is therefore used where increased mechanical strength is required. Keeping in view the unusually high flow rate at the site under consideration, ASTM A216 is selected as the material for runner construction. Besides strength, it also provides relatively better resistance against corrosion and sand erosion (see Appendix-K).

Drive System

The drive system transmits power from the turbine shaft to the generator shaft. It also has the function of changing the rotational speed from the one shaft to the other when the turbine speed is different to the required speed of the alternator or device.

The following options can be considered for micro hydropower drive systems:

- direct drive,
- flat belt and pulleys,
- V or wedge belt and pulleys,
- chain and sprocket,
- Gearbox.

Direct Drive

This system is only for the case where the shaft speeds are identical because it uses a flexible coupling to join the two shafts together directly. Due to its low maintenance, high efficiency (>98%) and low cost properties, selected for this thesis work. The only disadvantage is that the alignment is far more critical than with an indirect drive.

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CHAPTER SIX

ECONOMIC ANALYSIS OF MICRO HYDRO POWER

As with any other investment project, the economic feasibility of micro hydro projects must be verified to attract the interest of investors, It is also of key importance in enabling financial institutions to supply the funds necessary to finance the project in the promoter's own funds. A question a promoter has to answer prior to the decision to invest is taken include the following. What are the costs incurred by the project? What will be the revenues does the project generate a reasonable rate of return to their own investment funds? What are the financial sources?

6.1. Cost

The cost of an MHP is site- specific. It depends on the necessary civil works, the generating equipment and the electrical transmission/ distribution lines. While the cost of the generating equipment is almost a linear function of power size (in KW), the cost of civil works depends on the physical characteristics of the site . Similarly , the cost of electrical lines depends on the type of grid and on the distance to the connection point.

the development costs have to be taken into account : engineering studies, environmental impact studies and the legal fees to submit the project for approval to the different public bodies involved.

Besides the investment costs, which have to be paid off during the initial life of the project in the form of depreciation, operation and maintenance costs (O& M) have also to be estimated and depend mainly on the permanent personnel involve, on the insurance costs and on repair and maintenance contracts concluded with specialized firms. Certain expenses which will not be encountered every year, like major repair / maintenance of machinery and replacement of brushes, will also have to be take into account.
Payment of the debt and interest on bank loans will also need to be estimated. Usually the whole calculation is made in current cost in order to avoid making estimates of inflation. Cost evaluation must be conducted carefully because such projects are capital intensive and costs

depend very much on the characteristics of the site. In brief, the following typology of costs applies to micro hydro projects;

6.1.1. Initial costs

Feasibility Studies and project development are typical items of MHP projects. They include hydrological and environmental assessment, preliminary designs, permits and approvals (for water, land use and construction), land rights, interconnection studies, power purchase agreements (PPA), project management and financing fees.

6.1.2. Construction costs

This type of costs is incurred after the decision to go ahead with the project is taken. Such costs include engineering, insurance premiums, civil works and equipment.

6.1.3. Operation and Maintenance costs

These are regular costs that occur on a yearly basis and include transmission line maintenance, general administration, repairs and contingencies. Operation and maintenance cost most importantly include maintenance of the civil works and the equipment of the micro hydropower plant.

6.2. Assessing the Profitability of and MHP Project

Different summary measures are usually considered for the economic and financial appraisal of investment projects. Among the most frequently used measures we can identify the following:

Payback period: number of years necessary to recover the investment. Usually we encounter payback period from 5 to 10 years when assessing profitable MHPP projects, which themselves can have a life span of 25 years or more. This varies according to the investment needed, tariffs applied and Operation and maintenance expenditure.

Net present value (NPV): Sum of the discounted cash flows over the life time of the project assuming a discount rate.

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Table 6.1: Turbine Cost Analysis Using Package Soft Ware [14].

Head* (m):	76
Flow Rate* (m^3/sec):	.212
Calculate Reset Form	

Turbine Costs	
Pelton Turbine (£):	37000

Table 6.2: Electro Mechanical and investment Cost Analysis Using Package Soft Ware [14].

Head* (m):	76
Estimated Capacity* (kW):	126
Calculate Reset Form	

Estimated Values	
Estimated Cost of Electro-Mechanical Equipment (£):	111000
Estimated Investment Costs(£):	326000

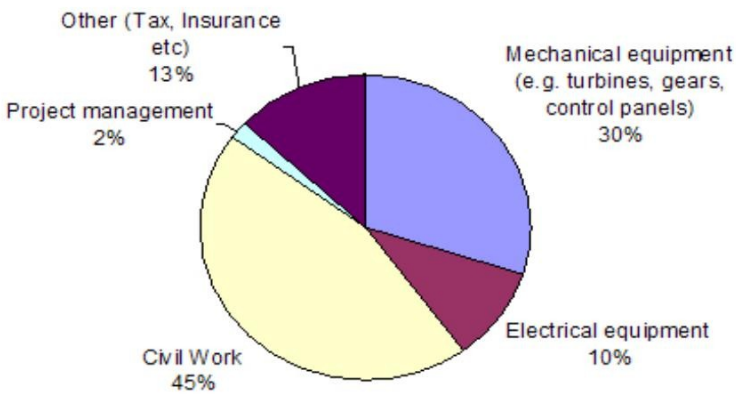

Figure 6.1: Cost Break Down of Micro Scale Hydro Power [14].

Table 6.3: Breakdown Capital Costs of Temie River Micro hydro power [29]

Item	**Cost(Etbx10^3)**	**Percentage (%)**	**Remark**
Civil Work	2073.15	45	Weir, Intake, Channel, Forbay, Penstock, Power House, Tailrace.
Electrical Equipment	691.05	15	Load controller, Electrical Generator, Transformer, Transmission and distribution Line.
Mechanical Equipment	1151.75	25	Control panels, Nozzle, Turbine, power transmission Shaft.
Project Management and others	691.05	15	Planning, Tax, Insurance, Transportation environmental impact and feasibility studies.
Total	4607	100	

In general, as seen from the above table 6.3. Cost of the power system is summarized. This cost break down analysis is takes in to account: - calculated dimensions and specifications determined in each section, world market manufacturers based on the specification, material and size determined, the package soft ware value like Table 6.1 and Table 6.2., and the percentage estimation cost that set in Figure 6.1.Finally after the consideration of all of these points, come to the current economy and market stipulation of the country that the plant is designed (see appendix-G).

The payback period is the length of time that it takes for a project to recoup its initial cost of the cash receipts that it generates. This period is sometimes referred to as ―the time takes for an investment to pay for itself‖. The basic premise of the payback period is that more quickly the cost of an investment can recovered, the more desirable is the investment. The specific energy cost of the system determines the payback period of the system. The specific energy cost can be calculated as follows.

$$\text{energycost} = \frac{\text{income per year}}{\text{annual energy consumptions}} \tag{61}$$

Whereas, the income per year is calculated with

$$incomeperyear = \frac{C_i}{\frac{(1+i)^n - 1}{[i(1+i)^n]}} \tag{6.2}$$

Where, i- the interest rate and it is considered as 10% for Ethiopian economic condition.

n- The number of year.

C_i – investment cost.

After substituting all the values the income per year from the system is 506770ETB/year. And from chapter three the annual energy demand including the pump power is 799350kWhr/year.

Therefore, the energy cost is

$$\text{energy cost} = \frac{\text{income per year}}{\text{annual energy consumptions}} = \frac{5067700\text{ETB /Year}}{799350 \,{}^{\text{kwhr}}\!/_{\text{year}}} = 0.634 \;\;{}^{\text{ETB}}\!/_{\text{kwhr}} \tag{6.3}$$

From the activity trends in the developed country the micro hydro power system the operation and maintenance costs 1% of the investment cost per year. Therefore, the annual operations and

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maintenance cost become 46070 /year. The expected annual saving cost per year is calculated as follows.

Annual Saving = [Cost per unit of electricity × (Annual electricity generated by the equipment)] - Annual Operation and Maintenance Cost.

= [0.634ETB/kWhr × (799350kWhr/year)] – 46070ETB/year = 461630ETB/year.

Therefore, the payback period of the system is

$$\text{paybackperiod} = \frac{\text{investmentcost}}{\text{Annual Saving}} = 9.98\ years \quad 6.4$$

Since in micro hydro power plant construction the great expense is investment cost. The maintenance and operation cost is not so much. There for the result of the payback period (PP) is not more than 10 years which is a reasonable period.

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CHAPTER SEVEN

RESULT AND DISCUSSION

As see from the Table 1.1., the total expense for energy is 1218233ETB per year. When we see the twenty five years expense, it will be 30455825.00 that are too large compared to the micro hydro power the twenty five years expense i.e. 5758750.00 and also currently the population have no TV and libratory equipment access. In addition to this, all of the energy sources that are listed in the Table 1.1. have their own negative impact on the environment and life of the society. Therefore when takes in account environmental pollution and total expense, the micro hydro power plant that designed by this theses is vital for the Dombit and saint marry monastery as well as for the local government.

As see from appendix-A and –B, the village that selected in this thesis is second block and the energy cost is 0.3564 for the domestic and 0.6088 for the commercial the average is 0.4826. And the calculated energy cost in this thesis is 0.634 (see equation 4.3) which is approximately the same to the current Ethiopia electric tariff. This indicated that cost analysis of the design is fair.

Here on the design of turbine the specific speed is 64.2rpm (see equation 5.27) which is indicated that the runner is categorized as fast runner turbine (see table 6.1 below). High specific speed for a given head will result in a smaller turbine and generator, with saving in capital cost. But it needs proper material selection that has better Mechanical properties (strength). For this work Carbon Steel ASTM A216 castings are selected in the reason that it has slightly higher strength and work at low temperature (see Appendix-M).

Table 7.2: Specific Speed of Various Turbines

Type	**Runner Ns (rpm)**		
	Slow	medium	Fast
Pelton	4 to 15	16 to 30	31 to 70
Francis	60 to 150	151 to 250	251 to 400
Kaplan	300 to 450	451 to 700	701 to 1100

For penton turbine, by using equation 4.5, the power is 91.25kw, to get analytically the bucket velocity which is the power will be maximum, differentiate the power with the bucket velocity by using turbine vector equation i.e. P= mu(v1-u)*(1-kcoseβ). And finally the power is maximum at v1 = 2u. From the result of the equation 5.4, u =0.5*v1 = 18.9m/s, to show this with soft ware for this thesis case use math lab.

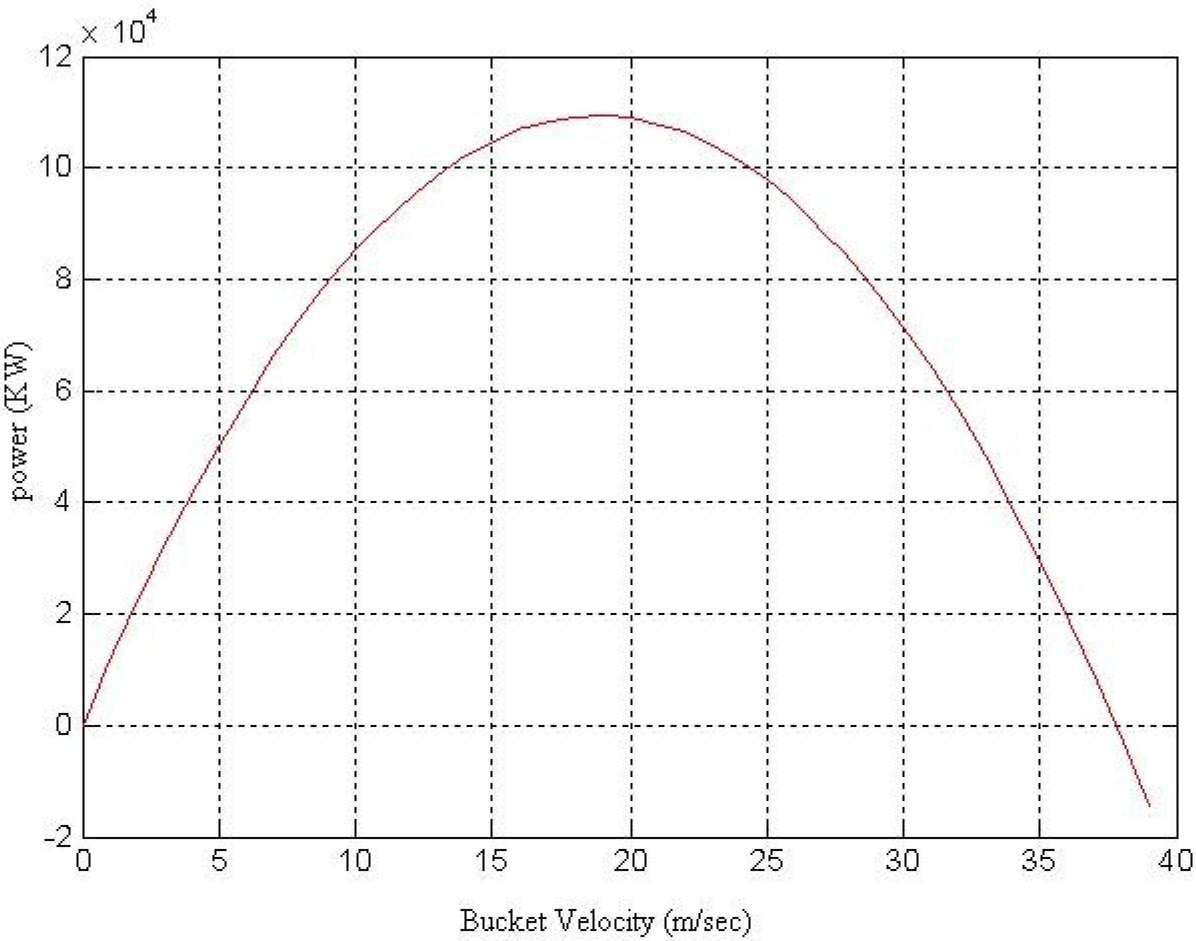

Figure 7.1: Bucket Velocity versus Power Graph.

As see from the graph at 18.9m/s bucket velocity, the power is around15.7KW which is less than that of done by analytically, this is due to some assumption like that of turbine efficiency and others, anyway the load that consumed by the site households have to less than this value, otherwise the bucket will be failed. Whereas for this thesis case the need is 91.34KW that is less than the maximum power there for the design is safe.

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CHAPTER EIGHT

CONCLUSION AND RECOMMENDATION

Micro-hydro power on Temie River has confirmed very successful as a tool to help Dombit and saint marry people to develop their economic position and to improve their life-style. It provides extra service in the area to reduce the toil of food processing and it can offer a means of generating electric power.

The total expenses of the society for power is reduced by 18.9% and also if the kebelle administration is try to use the power efficiently, they can improve their life style with additional service that is not listed in this thesis (see appendix- O) because rating capacity of the river (126KW) is larger than the current electric load demand of the village (91.25KW).

Exercising of the project practically is not only the success of the Dombit and saint marry village but also for the world because it mitigate environmental pollution.

The financing of the installation of the technology through loans and subsidies is needs careful planning.

In general most of the time, micro hydropower is installed in area, which far from the central grid (urban area) like Dombit and saint marry monastery, So there is luck of intellectual human power, who can maintain the plant when any trouble is occurred and also the economy of the society is not as much of. Therefore the local man powers have to train.

Currently in amhara region have more than 26 hydropower capacity, where as there is scarcity of electricity especially in rural areas, so anybody should toiling up to full fill the five year Government transformation plan by changing these micro hydro power sites in to practical work by takes as a reference this work.

As recommendation,

- In view of the fact that the government alone cannot afford electrifying rural areas of Ethiopia By micro hydropower, so maximum effort must be exerted to transform the current attitude towards the private investors and NGOs to electrify rural off grid areas like that of Dombit and Nib gasha villages.
- Even though the study is based on the selected site area, can apply other micro hydropower plants by changing value of the site data’s.

- As seen from the Appendix-P the population that dwell around the site river (Temie River) have been utilized the river for irrigation, due to this reason the flow rate of the river is dwindle year to year, typically these who live above the diversion of the plant. So before the installation of the plant, the Government as well as the local kebelle administration has to take an assignment to solve these problem see appendix-P.
- In the thesis the electrical part of the plant and some other parts are not sized, so anybody who is interested can go ahead these parts.

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APPENDIXES

Appendix-A: Current (Augest16, 2011) Ethiopia electric tariff for domestic Service

Division	Energy in kwh	Tariff in birr/kwh
1st block	0-50	0.273
2nd block	51-100	0.3564
3rd block	101-200	0.4993
4rth block	201- 300	0.55
5thblock	301-400	0.5666
6 th block	401-500	0.588
7th block	> 500	0.6943

Appendix-B: Current (Augest16, 2011) Ethiopia electric tariff for Commercial Service

Division	Energy in kwh	Tariff in birr/kwh
1st block	0-50	0.6088
2nd block	50 <	0.6943

Appendix-C: Small Hydro Power Potential Site and Rivers Capacity in Amhara National Regional State

No	Zone	Woreda	Name of River	Catch ment area (KM2)	River length (KM)	Energy potential (KW)	Head (M)	Discharge Flow (CMS)	Installation Capacity	Firm output (KW)
1	W/Gojjam	Mecha	Gilgel Abay	1148	66.5	164000	6	4.012	195.5	135.7
2	W/Gojjam	Achefer	Kilte	490	46.7	9260	5	0.397	14.43	5.3
3	W/Gojjam	B/Dar Zuria	Andassa - 1	401	65.7	21000	5.4	2.2	88.89	43.5
4	W/Gojjam	B/Dar Zuria	Andassa - 1	401	65.9	21400	11.6	1.03	88.89	88.8
5	W/Gojjam	B/Dar Zuria	Andassa - 1	401	66.2	21800	11.6	1.03	88.89	88.8
6	E/ Gojjam	Hunet ejju Enese	Temie	119	35.5	14300	76	0.212	122.2	122
7	E/ Gojjam	Hunet ejju Enese	Azawari-1	191	40.3	12500	5	0.797	28.86	9.5
8	E/ Gojjam	Hunet ejju Enese	Azawari-1	191	40.4	12600	76	0.212	122.2	122.2
9	W/Gojjam	B/Dar Zuria	Andassa Brach	298	27.9	11900	11.6	1.03	88.89	69
10	W/Gojjam	Mecha	Koga	174	34.5	13300	4.8	1.22	44.44	25.5
11	E/ Gojjam	Dejen	Suha shet	488	49.6	20300	92.1	0.212	166.66	166.6
12	E/ Gojjam	Dejen	Muga hayk	524	79.4	29600	47.3	0.446	166.66	168.6
13	W/Gojjam	Denbecha	Gula-1	221	36.4	34700	9.2	0.42	26	16.7
14	W/Gojjam	Denbecha	Gula-2	221	39.4	34800	11.4	0.522	40	22
15	W/Gojjam	Denbecha	Temcha	400	38.2	72900	14	0.6	59.8	59.8
16	E/ Gojjam	Machakel	Gedaba-1	677	70	107000	30.4	0.708	166.66	127
17	E/ Gojjam	Machakel	Gedaba-2	810	89.6	150000	45.1	0.62	222.2	195.7
18	W/Gojjam	Jabitenan	Lahi	366	51	37800	19	0.422	59.6	49
19	W/Gojjam	Jabitenan	Birr	186	30.4	7800	10	0.154	13.6	13.6
20	W/Gojjam	Banjashikudad	Fettam-1	216	28	6600	25	1.36	277.8	102
21	Awi	Wonberma	Fittame-3	720	89.1	122000	58	0.966	434	235
22	Awi	Ankisha	Fettam-2	305	48.5	25800	18	1.492	224	71.8
23	Awi	Dangila	Asher	338	41.2	35800	11	1.912	166.66	75.5
24	Awi	Gowangoa	Ardie	251	52.6	35600	14.5	0.788	92	80
25	Awi	Gowangoa	Dura	619	74.8	151000	26	2.364	519	228
26	E/ Gojjam	Gozamen	Chemoga Yeda (I %&ii)			1391(GW H/Yr)			290(MW)	

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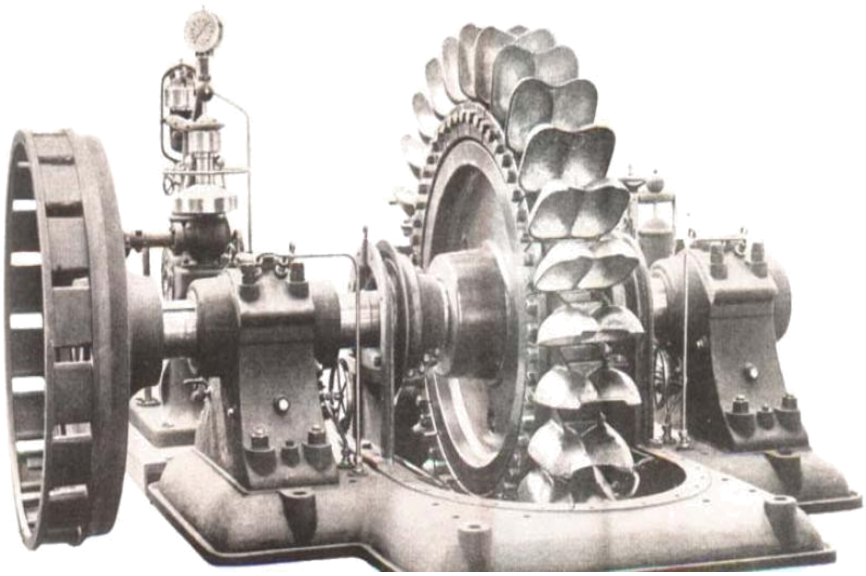
Generator:

Model	SF
Rated Capacity (KW)	100KW-80MW
Rated output (KW)	100KW-80MW
Rated voltage(KV)	0.4, 6.3, 6.6, 10.5
Rated speed	150-1500rpm

Appendix-D: Penton Turbine Model and Rated Capacity



Appendix-E: Coupling of Pentone Turbine with Generator

Appendix-F: Model of Different Turbine and Generator

Type / Item	Francis	Kaplan	Pelton, Turgo	Tubular , Bulb
Turbine				
Model	HL	ZD, ZZ	CJ, XJ	GD, GZ
Rated head (m)	10 - 300 m	2 - 70 m	70 - 1600 m	2 - 20 m
Rated flow (m 3 /s)	0.3 - 100	1.0 - 200	0.1 - 20	1.0 - 250
Rated speed (rpm)	68.2 – 1500 rpm	68.2 – 750 rpm	150 – 1500 rpm	75 – 500 rpm
Rated output (KW)	100KW-100MW	100KW-100MW	100KW-80MW	200KW-60MW
Runner Diameter (M)	0.4 – 6.0 m	0.8 - 8.0 m	0.8 - 6.0 m	0.8 – 6.0 m
Generator				
Model	SF	SF	SF	SF
Rated Capacity (KW)	100KW-100MW	100KW-100MW	100KW-80MW	200KW-60MW
Rated output (KW)	100KW-100MW	100KW-100MW	100KW-80MW	200KW-60MW
Rated voltage(KV)	0.4, 6.3, 6.6, 10.5	0.4, 6.3, 6.6,10.5	0.4, 6.3, 6.6, 10.5	0.4, 6.3, 6.6, 10.5
Rated speed	68.2-1500rpm	68.2-750rpm	150-1500rpm	75-500rpm

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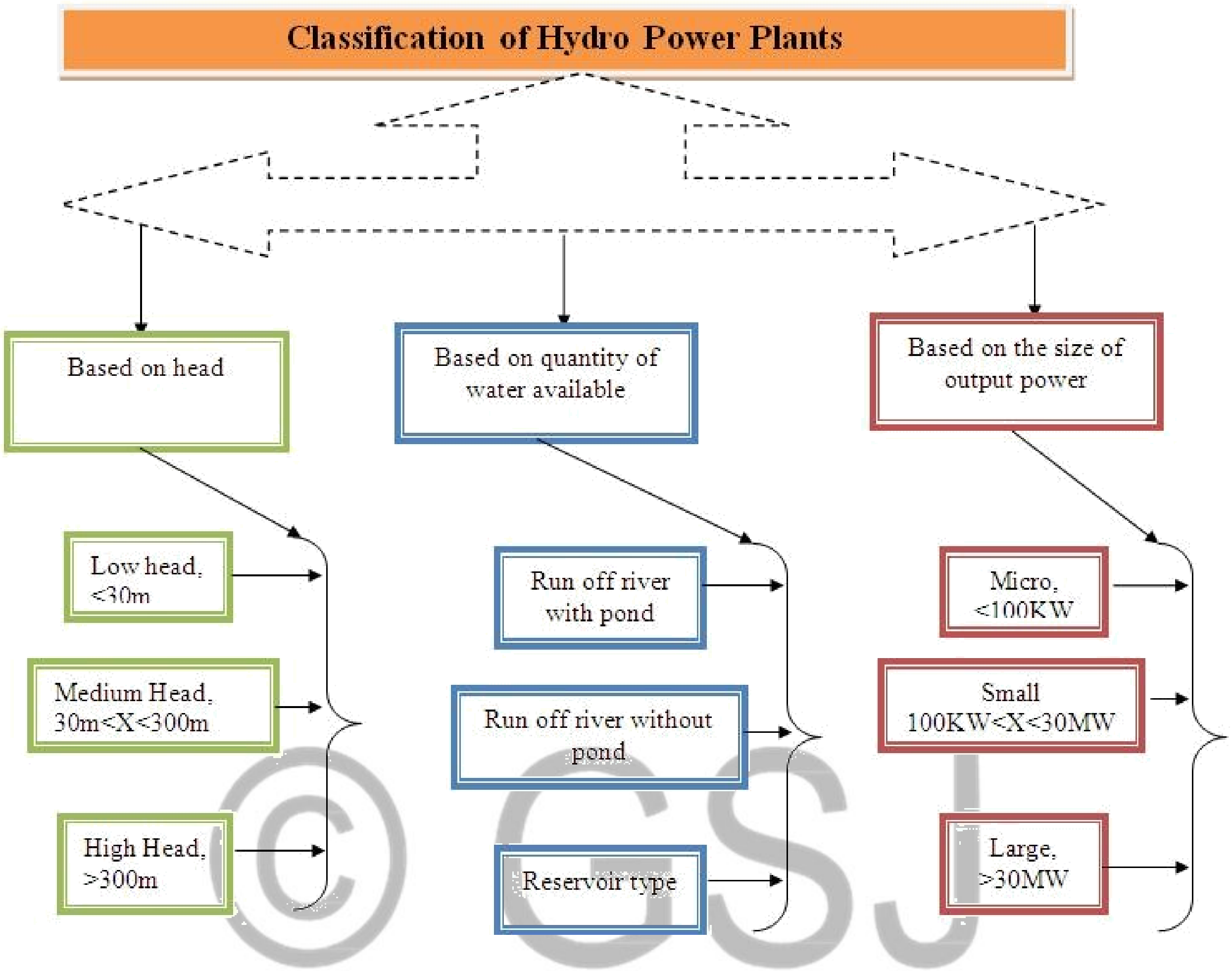
Appendix-F: Electrical Components of micro hydro power

components		
	for 10 - 50 kW	**for 10 - 300 kW**
generator	IMAG of 50 Hz, 4 or 6 pole, 400 V, 3 phase[252]	synchronous generator of 50 Hz, 4 or 6 pole, 400 V, 3-phase
	for IMAG	**for synchronous generator**
control	IGC, voltage meter, ampere meter	ELC, voltage meter, ampere meter, frequency and rotational speed meter, kWh meter
	for < 1.5 km distance	**for > 1.5 km**
transformer	no transformer needed	step-up and step-down 0.4/15 kV and 15/0.4 kV transformer
transmission	-	3 phase - 3 wire, 15 kV, 20 mm² ACSR up to 30-40 km distance, on impregnated wooden poles 10 m long at span of 50 m
distribution (EEPCO standard)	3 phase - 4 wire (380/220 V); 25 mm² or 50 mm² AAC phase line,15 mm² respectively 25 mm² neutral line; on impregnated wooden poles 8 m long at span of 30 m	
protection	- earthing of all appliances in the power house through a buried grid - over-voltage protection as minimum - lightning arrestors	- earthing of all appliances in the power house through a buried grid connected to the penstock - steel rod at the transformer - lightning arrestors circuit breakers over- and under-voltage, over-current and under-frequency; < 30 kW under-voltage / under-frequency protection is not mandatory

Appendix-G: Man power cost Estimation for the construction of micro hydro power

capacity range	roughly estimated system costs per kW [ETB/kW] 279	investment cost for the named range [ETB]	average invest-ment cost [ETB]	manpower	monthly salary [ETB]	required number	approximate construction period [months]	manpower costs [ETB]	percentage of investment cost
5 - 20 kW	12,000	60,000	150,000	unskilled labourers	250	15	3	11,250	
		240,000		skilled labourers (ma-son, carpenter, lock-smith)	400	3	3	3,600	
				experienced coordinator (e.g. operator of the mill)	800	1	3	2,400	
				total				17,250	**11.50%**
20 - 80 kW	20,000	400,000	1,000,000	unskilled labourers	250	15	12	45,000	
		1,600,000		skilled labourers (ma-son, carpenter, lock-smith, electrician)	400	4	12	19,200	
				MHP-specialist (engi-neer or turbine manu-facturer)	2,000	1	12	24,000	
				total				88,200	**8.82%**
80 - 300 kW	15,000	1,200,000	2,850,000	unskilled labourers	250	20	18	90,000	
		4,500,000		construction enterprise or workshop with skilled labourers (masons, car-penters, locksmiths, electricians)	400	8	18	57,600	
				engineers (civil and electrical engineers, coordinator)	2500	3	18	135,000	
				total				282,600	**9.92%**



Appendix-H: Classifications of Micro Hydropower Plants

Appendix-I: Generator Synchronization Speed

Number of poles	50 Hz	60 Hz	Number of poles	50 Hz	60 Hz
2	3000	3600	16	375	450
4	1500	1800	18	333	400
6	1000	1200	20	300	360
8	750	900	22	272	327
10	600	720	24	250	300
12	500	600	26	231	277
14	428	540	28	214	257

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Appendix-J: Penstock Material and Sizing

Pipe size →	4 in.			6 in.			8 in.			10 in.			12 in.		
Pipe material ↓	t_w	P_R	S_A	t_w	P_R	S_A	t_w	P_R	S_A	t_w	P_R	S_A	t_w	P_R	S_A
Steel	0.24	1400	57	0.28	1200	56	0.25	800	54	0.25	640	52	0.25	540	51
							0.32	1100	56	0.37	1030	55	1.38	890	54
													0.41	1000	55
PVC (polyvinyl chloride)	0.11	100	12	0.16	100	12	0.21	100	12	0.26	100	12	0.31	100	12
	0.17	160	15	0.25	160	15	0.33	160	15	0.41	160	15	0.49	160	15
	0.26	250	18	0.39	250	18	0.51	250	18	0.63	250	18	0.75	250	18
PE (polyethylene)	0.265	100	9	0.39	100	9	0.51	100	9	0.63	100	9	0.75	100	9
	0.41	160	11	0.60	160	11	0.78	160	11	0.98	160	11	1.16	160	11
	0.62	250	13	0.91	250	13	1.18	250	13	1.47	250	13	1.75	250	13
A-C (transite—asbestos cement)	0.32	100	41	0.46	100	41	0.56	100	40	0.62	100	39	0.72	100	38
	0.41	150	44	0.53	150	43	0.63	150	41	0.83	150	42	0.96	150	41
	0.41	200	44	0.66	200	45	0.81	200	45	1.02	200	45	1.18	200	44
FRP (fiber reinforced epoxy)	0.07	225	17	1.11	250	16	0.14	225	16	0.18	225	15	0.21	225	15

Pipe size →	14 in.			16 in.			18 in.			20 in.			24 in.[a]		
Pipe material ↓	t_w	P_R	S_A	t_w	P_R	S_A	t_w	P_R	S_A	t_w	P_R	S_A	t_w	P_R	S_A
Steel	0.25	490	50	0.25	430	49	0.25	380	48	0.25	340	47	0.25	280	45
	0.38	810	54	0.38	710	52	0.38	630	52	0.38	570	51	0.38	470	
	0.44	970	55	0.50	990	55	0.50	880	54	0.50	790	53	0.50	660	
										0.59	950	54	0.69	940	54
PVC (polyvinyl chloride)	← PVC pressure pipe not available →														
PE (polyethylene)	0.82	100	9	0.94	100	9	1.06	100	9	1.12	100	9	1.41	100	9
	1.27	160	11	1.46	160	11	1.64	160	11	1.81	160	11			
	1.92	250	13												
A-C (transite—asbestos cement)	0.74	100	38	0.83	100	37	0.95	100	37	1.06	100	37	1.24	100	
	1.11	150	41	1.23	150	41	1.47	150	42	1.64	150	42	1.98	150	
	1.38	200	44	1.57	200	44	2.09	200	45	1.98	200	45	2.81	200	45
FRP (fiber reinforced epoxy)	0.26	225	15	0.29	225	15									

Appendix-K: comparison of penstock materials

material	Friction	Weight	Corrosion	Cost	Joining	Pressure
Ductile iron	****	*	****	**	****	****
Asbestos sement	***	****	****	***	***	*
concrete	*	*	*****	***	***	*
Wood stave	***	***	****	**	****	***
GRP	*****	*****	***	*	****	*****
UPVC	*****	*****	****	****	****	*****
mildsteeel	***	***	***	****	****	*****
HDPE	*****	*****	*****	**	**	*****

*= poor, *****= Excellent

Appendix-L: Material Properties

Properties	Carbon Steels	Alloy Steels	Stainless Steels	Tool Steels
Density (1000 kg/m^3)	7.85	7.85	7.75-8.1	7.72-8.0
Elastic Modulus (GPa)	190-210	190-210	190-210	190-210
Poisson's Ratio	0.27-0.3	0.27-0.3	0.27-0.3	0.27-0.3
Thermal Expansion (10^{-6}/K)	11-16.6	9.0-15	9.0-20.7	9.4-15.1
Melting Point (°C)			1371-1454	
Thermal Conductivity (W/m-K)	24.3-65.2	26-48.6	11.2-36.7	19.9-48.3
Specific Heat (J/kg-K)	450-2081	452-1499	420-500	
Electrical Resistivity ($10^{-9}\Omega$-m)	130-1250	210-1251	75.7-1020	
Tensile Strength (MPa)	276-1882	758-1882	515-827	640-2000
Yield Strength (MPa)	186-758	366-1793	207-552	380-440
Percent Elongation (%)	10-32	4-31	12-40	5-25
Hardness (Brinell 3000kg)	86-388	149-627	137-595	210-620

Appendix-M: ASTM Cross Reference Material Specification

Material	Forgings	Castings	Wrought Fittings
Carbon Steel Cold Temperature Service	A105 A350-LF2	A216-WCB	A234-WPB A420-WPL6
Carbon-1/2 Molybdenum Alloy Steel High Temperature Service	A182-F1	A217-WC1 A352-LC1	A234-WP1
3-1/2 Nickel Alloy Steel Low Temperature Service	A350-LF3	A352-LC3	A420-WPL3
1/2 Cr-1/2 Mo Alloy Steel 1/2 Cr-1/2 Mo-1 Ni Alloy 3/4 Cr-1 Mo-3/4 Ni Alloy Steel 1 Cr-1/2 Mo Alloy Steel	A182-F2 A182-F12 CL2	A217-WC4 A217-WC5	A234-WP12 CL2
1-1/4 Cr-1/2 Mo Alloy Steel 2-1/4 Cr-1 Mo Alloy Steel 5 Cr-1/2 Mo Alloy Steel 5 Cr-1/2 Mo Alloy Steel 9 Cr-1 Mo Alloy Steel 13 Cr Alloy Steel	A182-F11 CL2 A182-F22 CL3 A182-F5 A182-F5a A182-F9 A182-F6	A217-WC6 A217-WC9 A217-C5 A217-C12 A743-CA15	A234-WP11 CL2 A234-WP22 CL3 A234-WP5 A234-WP9
Type 304 Stainless Steel (18 Cr-8 Ni) Standard Low Carbon High Temperature Service	A182-F304 A182-F304L A182-F304H	A351-CF3 A351-CF8	A403-WP304 A403-WP304L A403-WP304H
Type 310 Stainless Steel (25 Cr-20 Ni) Type 316 Stainless Steel (16 Cr-12 Ni-2 Mo) Standard Low Carbon High Temperature	A182-F310H A182-F316 A182-F316L A182-F316H	A351-CK20 A351-CF3M A351-CF8M	A403-WP310 A403-WP316 A403-WP316L A403-WP316H
Type 317 Stainless Steel (18 Cr-13 Ni-3 Mo) Type 321 Stainless Steel (18 Cr-10 Ni-Ti) Standard High Temperature Service	A182-F321 A182-F321H		A403-WP317 A403-WP321 A403-WP321H
Type 347 Stainless Steel (18 Cr-10 Ni-Cb) Standard High Temperature Service	A182-F347 A182-F347H	A351-CF8C	A403-WP347 A403-WP347H
Type 348 Stainless Steel (18 Cr-10 Ni-Cb) Standard High Temperature Service	A182-F348 A182-F348H		A403-WP348 A403-WP438H

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Appendix-N: Renewable energies in all country in the world

Country	Year	Total renewable (TWh)	Hydro (GWh) [12]	Wind (GWh)[2]	Biomass (GWh)	Solar (GWh)[3]	Geothermal (GWh)[4]	% of total generation
Afghanistan	2008		520					62.50
Albania	2008 [13]	3.850	3,850					100.00
Algeria	2009		310					0.77
Angola	2008		3,804					96.45
Argentina	2008		29,955	40	1,551			27.33
Armenia	2008		1,779	2				30.38
Australia	2009		11,442	3,615	1,972	148	0	7.40
Austria	2008		40,678	2,014	4,264	28	2	70.02
Azerbaijan	2008		2,210					9.80
Bangladesh	2008		1,459					4.43
Belarus	2008		39	1	77			0.35
Belgium	2008		1,757[14]	996(2009)		166(2009)		6.53
Belize	2008		204					94.88
Benin	2008		1					0.78
Bhutan	2008		7,063					99.97
Bolivia	2008		2,258		177			40.71
Bosnia and Herzegovina	2008		4,506					35.50
Brazil	2009 [15]		387,078	1,374	21,354			88.88
Bulgaria	2007[6]		3,234	47				8.45
Burkina Faso	2009		131					19.73
Burma	2008		3,988					62.06
Burundi	2008		206					99.04
Cambodia	2008		46		4	2		3.78
Cameroon	2008		4,190					77.29
Canada	2009 [16]		363,400	6,100		17 (2007)		64.23
Cape Verde	2008	0.257		7				2.73
Central African Republic	2008	0.160	0.130					81.25
Chile	2008		23,643	36	2,929			44.14
China	2008	576.1	486,700	5,600[17]				17.88
Colombia	2008		43,085	51	561			85.66
Comoros	2008	0.052	2					3.85
Republic of the Congo	2008	0.452	371					82.08
Costa Rica	2008		7,313	188	78		1,075	93.15
Cote d'Ivoire	2008		1,879		112			35.89
Croatia	2008		5,164	38	20			44.79
Cuba	2008		137		371			2.99
Cyprus	2008				10	3		0.28
Czech Republic	2008		2,376	245	1438	13		4.88
Democratic Republic of the Congo	2008		7,409					99.42
Denmark	2009[18]			6,721	2,983	2.7		27.4
Dominica	2008		32					36.78
Dominican Republic	2008			1,711		28		11.93
Ecuador	2008		11,181	3	397			64.12

Egypt	2008		14,535	884				12.44
El Salvador	2008		2,018		100		1,443	62.24
Equatorial Guinea	2008		2					2.17
Eritrea	2008	0.270				2		0.74
Estonia	2009[6]		32	195	39 (2006)			3.03
Ethiopia	2008		3,263				13	88.18
Faroe Islands	2008[19]	0.153	147	7				61.85
Fiji	2009		660					68.04
Finland	2009		12,588	262	8,586	6		31.56
France	2008		68,841	5,689	2,116	41		13.34
Gabon	2008		885		7			45.44
Georgia	2008		7,090					85.50
Germany	2010[11]	101.681	19,694	36,500	33,460	12,000	27	16.50
Ghana	2008		6,133					75.09
Greece	2009		4,694	1,887	199	5		13.18
Guatemala	2008		3,675		1,474			61.33
Guinea	2008		500					54.35
Haiti	2008		179					38.41
Honduras	2008		2.268		187			39.21
Hungary	2009		226	315	2,323	1		8.44
Iceland	2009		12,156		1		4,325	99.99
India	2009		104,439	15,300	2,000	42		14.58
Indonesia	2008		11,413		55		7,882	13.71
Iran	2010		16,100	128	1	4	1	20.69
Iraq	2008		555					1.60
Ireland	2007[20]	2.758	667	1,959	133	5 (2001)	10 (2001)	10.15
Israel	2008		16	9	209			0.44
Italy	2010 [21]	75.270	50,582	8,449	9,281	1,600	5,358	22.2
Jamaica	2008		156	47	102			4.16
Japan	2007	95.0	86,350	1,754		2	3,027	9.41
Jordan	2008		61	3	9			0.56
Kazakhstan	2009		7,496					9.91
Kenya	2008		2,821		305		1,120	62.53
Kyrgyzstan	2009 [22]		10,098					91.11
Laos	2008		3,680					92.46
Latvia	2008		3,078	56	42			62.10
Lebanon	2008		369					3.69
Lesotho	2008	0.200	200					100.00
Lithuania	2009 [23]		424	157	66 (2008)		29	4.40
Luxembourg	2009		97	61	113	19		10.87
Republic of Macedonia	2008		832					13.92
Madagascar	2008		735					66.82
Malawi	2008		1,451					86.58
Malaysia	2009		8,640				1	8.54
Mali	2008		275					56.12
Mauritania	2008		60					10.97
Mauritius	2008		100					4.16

Mauritius	2008		100					4.16
Mexico	2009		26,410	237	823	9	6,403	14.17
Moldova	2008		81					2.37
Montenegro	2008		1,530					57.52
Morocco	2008		920	283				6.17
Mozambique	2008		14,963					99.92
Namibia	2008		1,556					70.82
Nepal	2008		3,042					99.67
Netherlands	2009[24]		98	4,581	5,422	46		8.94
New Caledonia	2008		440					24.44
New Zealand	2010[25]		24,470	1,618	572		5,551	74
Nicaragua	2008		529		321		306	33.81
Nigeria	2008		5,664					28.14
North Korea	2008		13,927					61.85
Northern Mariana Islands	2001			1		1	0	
Norway	2009 [26]		126,077	977	277[10]			96.63
Pakistan	2009		27,075					30.34
Palau			18					
Panama	2008		3,933		18			63.29
Papua New Guinea	2008		900					30.35
Paraguay	2008 [27]	54.912	54,909					100.00
Peru	2008		18,850	1	472			60.53
Philippines	2009		9,690	61	13	1	10,187	33.71
Poland	2009		2,385	1,038	4,976			5.92
Poland	2009		2,385	1,038	4,976			5.92
Portugal[28]	2010[28]	28.233	16,249	9,024	2,191	213	173 (2009)	52.0
Puerto Rico	2008	20.921	156					0.75
Réunion	2008		633					37.17
Romania	2006 [29]	18.4		76 (2008)				27.49
Russia	2009		162,270	5	2,400		442	17.83
Rwanda	2008		30					18.75
Saint Vincent and the Grenadines	2008		23					17.42
Samoa	2009		49					45.37
Sao Tome and Principe	2008		10					24.39
Serbia	2009		11,100					29.7
Senegal	2008		227		29		2	10.56
Sierra Leone	2008		18					31.03
Slovakia	2009		4,417	5	508			19.96
Slovenia	2008		3,959		277	1		27.10
South Africa	2008		1,247	246	30	21		0.65
South Korea	2009		2,785	646	533	945		1.18
Spain	2010 [30]		38,001	42,976	2,167 (2006)	7,276		30.62
Sri Lanka	2008		4,087	3	2	15		46.18
Sudan	2008		1,448					33.50
Suriname	2008		875					55.38
Swaziland	2008		200					42.55
Sweden	2009		64,473	2,361	11,321	5		60.42
Switzerland	2009		35,315	18	2,314	32		58.52

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Syria	2008		2,843					7.35
Tajikistan	2009 [31]		15,900					98.76
Tanzania	2008		2,628					61.39
Thailand	2008		7,042		4,593	3	2	8.37
Togo	2008		90		2			58.60
Trinidad and Tobago	2008						10	0.13
Tunisia	2008		38	37				0.52
Turkey	2010		59,504	5,832	937	0	946	25.32
Turkmenistan	2008		3					0.02
Uganda	2008		1,631					74.95
Ukraine	2008		11,268	43				6.24
United Kingdom	2006 [32]	22.464	7,891	5,274 [33]	9,291 [34] (2007)	8		6.18
United States	2009 [7]	413.21	272,100	70,800	54,300	808	15,200	10.05
Uruguay	2008		4,460		787			61.92
Uzbekistan	2009		9,237					19.47
Venezuela	2009		85,839					69.57
Vietnam	2008		25,726					36.77
Zambia	2008		9,569					99.71
Zimbabwe	2008		4,220					54.64

Appendix-O: Tungu Kabri Micro Hydropower Components and Appliances

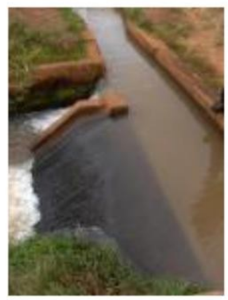
Intake

Water control at intake Canal

Water crossing

Canal

Settling tank



Spillway

Forebay

Forebay cleaning

Powerhouse

Penstock

Powerhouse

Turbine

Generator

Tailrace

Power distribution

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Small businness

Barbershop

Battery charging

Battery charging

Cellphone charging

Welding

Welding

Appendix-P: Irrigation on Temie River