Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 16 Issue 6 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Design and Analysis of Small Hydro Power for Rural Electrification

By Alie Wube Dametew
Wollo University KioT

Abstract- Hydropower, large and small, remains by far the most important of the "renewable" for electrical power production worldwide. Small-scale hydro is in most cases "run-of-river", with no dam, and is one of the most cost-effective and environmentally benign energy technologies to be considered both for rural electrification in less developed countries and developed countries for further hydro developments countries(like Ethiopia). This paper addresses power generation for rural applications by means of small hydropower plants by using cross-flow turbine systems .The cross-flow turbine is suitable for installing small hydro-electric power plants in case of low head and flow rate. Using mathematical analysis a complete design of such turbines has been done in this paper.

Keywords: design and analysis, hydro power, rewnable energy.

GJRE-F Classification: FOR Code: 290901

Design and Analysis of Small Hydro Power for Rural Electrification

Alie Wube Dametew

Abstract- Hydropower, large and small, remains by far the most important of the "renewable" for electrical power production worldwide. Small-scale hydro is in most cases "run-of-river", with no dam, and is one of the most cost-effective and environmentally benign energy technologies to be considered both for rural electrification in less developed countries and developed countries for further hydro developments countries(like Ethiopia). This paper addresses power generation for rural applications by means of small hydropower plants by using cross-flow turbine systems .The cross-flow turbine is suitable for installing small hydro-electric power plants in case of low head and flow rate. Using mathematical analysis a complete design of such turbines has been done in this paper. The complete design parameters such as, Turbine material, runner diameter, runner length, water jet thickness, blade spacing, radius of blade curvature, turbine power, turbine speed, number of blades, and any losses in the pipe due to friction, were determined at maximum turbine efficiency. Small Hydro turbine System Design Operation procedure, Recommendations and possible economic impact for small hydropower generation are also highlighted.

Keywords: design and analysis, hydro power, rewnable energy.

Chapter-One

I. Introduction and Back Ground of the Study

a) Introduction

The demand for energy is growing throughout the world. A combination of population growth, desire for improved living standards, and public policy has increased interest in green energy sources. Reliable access to electricity is a basic precondition for improving people's lives in rural and urban areas, for enhanced health care and education, and for growth within local economies (By Ryan Cook, 2012). At present, more than 1.5 billion people worldwide do not have access to electricity in their homes (Kari Sørnes, 2010). An estimated 80% of these people live in rural areas; most have scant prospects of gaining access to electricity in the near future. According to International Energy Agency projections, by 2030, the number of people without electricity is not likely to drop due to population growth (www.ruralelec.org). Hence Electrical energy is an essential component in the developing process of any given location of the globe. Therefore, rural electrification remains an important issue in many countries. More often rural areas, which can also be seen as developing areas, are prone to several electrification problems and a common alternative to this has been for decade the use of diesel power supplies. However, diesel supplies are environmentally not friendly, less reliable and less efficient. A better alternative could be the use of renewable energy sources (such as, hydro-turbine, Biomass and wind-turbine), in order to achieve optimum system design in terms of cost and efficient load demand satisfaction.

Author: Department of Mechanical Engineering, Kombolcha Institute of Technology Wollo University (WUKioT), Kombolcha –Ethiopia.
e-mail: wubealie@gmail.com

b) Back Ground of the Study

Hydro-power is considered as one of the most desirable source of electrical energy due to its environmental friendly nature and extensive potential available through out the world. Within the scope of hydro-electric power, small power plants have gained much attention in recent years. Small Hydro power Plants, being a mature technology may be optimally employed for sustainable power generation in rural communities in world wide. Hydropower plants convert potential energy of water at a height to mechanical energy which is used to turn a turbine at a lower level for generation of electricity (Anyaka Boniface Onyemaechi, 2013). In rural areas, small run-of-river hydro turbine is suitable for electrification because it is green, inexpensive, not fuel dependent, and is simpler to implement than other green energy technologies. A small hydropower scheme requires both water flow and a drop in height called a head to produce useful power. Water in nature is considered a source of power when it is able to perform useful work, particularly turn water wheels and generate electricity at a rate such that the development of power can be accomplished in a most efficient and economical way(Adejumobi, I.A, (2011). The research concerns to generate electric power From Small rivers and waterfalls could generate electricity to energize many off-grid rural areas in Ethiopia.in addition to this the power gereateted by constracting small dam or by the water water fill with two Continaeres and circulating them, and then to generet Power.

c) Problem Statement

In our country rural electrification will always be a challenging responsibility, due to reasons such as:

- The spreading of the villages
- The complications with grid extension alternatives

Global Journal of Researches in Engineering (F) Volume XVI Issue VI Version I Year 2016

- The relatively high electrification cost, especially for customers with low income
- The limitations of diesel power. However, substantial amount of Hydro -power is usually available in rural areas, and electric power generation systems are often installed in these areas but still it is cost. Local electricity generation from hydro-turbine(Hydro powe) could overcome the above drawbacks and provide better economical alternative for the electrification system in remote and rural areas. This paper shows the design, analysis and fabrication of small rural hydro-turbine electric power system.

d) *Objective of the study*

The main objective of the study is to design and Analysis of small scal hydro power.

i. Specific objective of the paper

- Select the proper materials for production of small rural electric power
- Design , and analysis of \ small hydro turbine rural electric power
- Contribute rural electrification system
- To develop a sustainable, environmentally friendly alternative Renewable energy production (Contribute green environment /environmental friendly).

e) *Scope of the paper*

- ✓ Select proper material for small Hydro pwer
- ✓ Asses the potentials and Impacts of Small Hydro power for development
- ✓ Design and analysis of small rural electric power
- ✓ System Design of Samall hydro power

f) *Research Methodology*

- In order to solve problems, engineers follow and apply different procedure and principles based on the problem identifications. This project focus on the following activities
- Collecting relevant data related to hydro power
- Design, analysis of hydro-turbine systems using mathematical and Numerical Methods(Matlab)
- Drive systems and opraing principles
- Hydro-turbine system Design and Development
- Prepare Fabrication procedure each elements of hydro turbine components
- Sammury and conclusion of the project

II. Literature Review

a) *General*

Hydropower energy has the greatest potential of all the sources of renewable energy and if only a small amount of this form of energy is used, it will be one of most important supplies of energy specially when other sources in the country have depleted. hydroelectric power comes from water at work, water in motion. it can be seen as a form of solar energy, as the sun powers the hydrologic cycle which gives the earth its water. In the hydrologic cycle, atmospheric water reaches the earth's surface as precipitation [Adejumobi, I.A,2011]. Some of this water evaporates, but much of it either percolates into the soil or becomes surface runoff. Water from rain and melting snow eventually reaches ponds, lakes, reservoirs, or oceans where evaporation is constantly occurring. Moisture percolating into the soil may become ground water (subsurface water), some of which also enters water bodies through springs or underground streams. Ground water may move upward through soil during dry periods and may return to the atmosphere by evaporation. Water vapor passes into the atmosphere by evaporation then circulates, condenses into clouds, and some returns to earth as precipitation. Thus, the water cycle is complete. Nature ensures that water is a renewable resource.

Current hydro power status (World Wide)

Hydropower, large and small, remains by far the most important of the 'renewables' for electrical power production worldwide. The World Hydropower Atlas 2000, published by the International Journal of Hydropower and Dams, reported that the world's technically feasible hydro potential is estimated at 14,370 TWh/year, which equates to 100% of today's global electricity demand. The economically feasible proportion of this is currently considered to be 8080 TWh/yr. The hydropower potential exploited in 1999 was 2650 TWh/yr, providing 19% of the planet's electricity from an installed capacity of 674 W. 135 W of new hydro capacity is expected to be commissioned in the period 2001–10. All other renewable combined provided less than 2% of global consumption. As illustrated in Fig. 1,

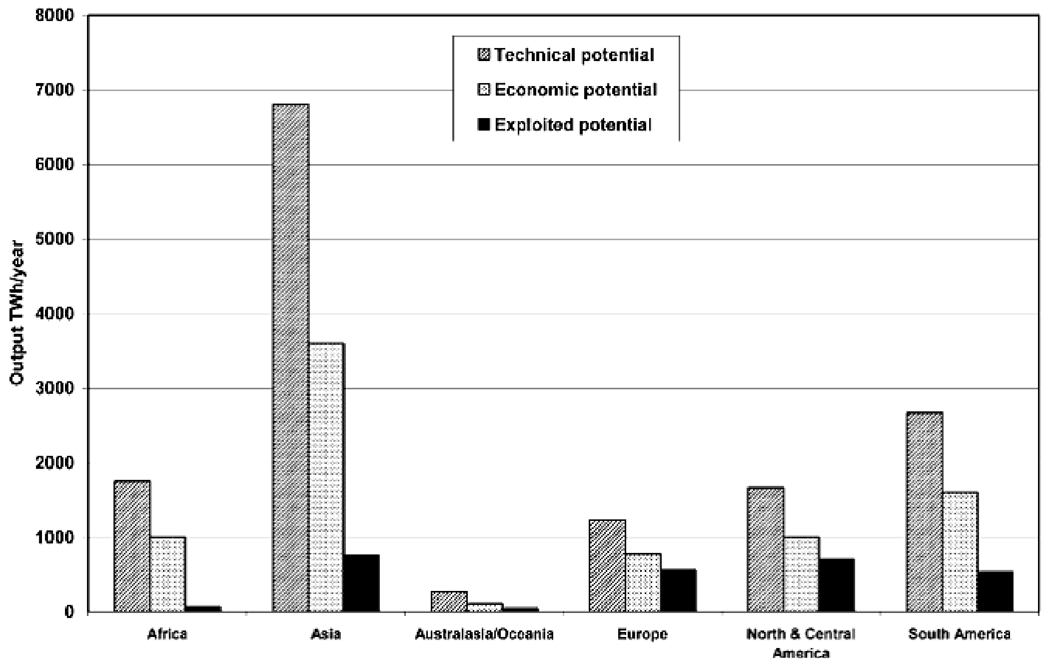

Fig. 1: Exploited hydro potential by continent

North America and Europe have developed most of their economic potential, but huge resources remain in Asia, Africa and South America. Small hydro (<10 MW) currently contributes over 40 GW of world capacity. The global small hydro potential is believed to be in excess of 100 GW. China alone has developed more than 15 GW, and plans to develop a further 10 GW in the current decade.

Small-scale hydro Hydropower (World wide)

Hydropower on a small-scale is one of the most cost-effective energy technologies to be considered for rural electrification in less developed countries. It is also the main prospect for future hydro developments in Europe, where the large-scale opportunities have either been exploited already, or would now be considered environmentally unacceptable. Small hydro technology is extremely robust (systems can last for 50 years or more with little maintenance) and is also one of the most environmentally benign energy technologies available [Anyaka Boniface,2013]. The development of hydro-electricity in the 20th century was usually associated with the building of large dams. Hundreds of massive barriers of concrete, rock and earth were placed across river valleys world-wide to create huge artificial lakes. While they created a major, reliable power supply, plus irrigation and flood control benefits, the dams necessarily flooded large areas of fertile land and displaced many thousands of local inhabitants [Igbinovia, S.O,2007]. In many cases, rapid silting up of the dam has since reduced its productivity and lifetime. There are also numerous environmental problems that can result from such major interference with river flows. Small hydro is in most cases 'run-of-river'; in other words any dam or barrage is quite small, usually just a weir, and generally little or no water is stored[Ryan Cook,2012]. The civil works purely serve the function of regulating the level of the water at the intake to the hydro-plant. Therefore run-of-river installations do not have the same kinds of adverse effect on the local environment as large hydro. Hydropower has various degrees of 'smallness'. To date there is still no internationally agreed definition of 'small' hydro; the upper limit varies between 2.5 and 25 MW. A maximum of 10 MW is the most widely accepted value worldwide, although the definition in China stands officially at 25 MW. In the jargon of the industry, 'mini' hydro typically refers to schemes below 2 MW, micro-hydro below 500 kW and pico-hydro below 10 kW. These are arbitrary divisions and many of the principles involved apply to both smaller and larger schemes (Oliver Paish,2002).

Global Journal of Researches in Engineering (F) Volume XVI Issue VI Version I Year 2016

Table 1: The Development and Current hydro power status in Ethiopia

Population	91,195,675
Area	1,104,300 km^2
Topography	High plateau with central mountain range divided by Great Rift Valle High plateau with central mountain range divided by Great Rift Vally.
Rain Pattern	Mean annual rainfall ranges from 2,000 mm over some pocket areas in the southwest highlands, and less than 250 mm in the lowlands. In general, annual precipitation ranges from 800 to 2,200 mm in the highlands (altitude >1,500 m) and varies from less than 200-800 mm in the lowlands (altitude <1,500 m).2 Parts of Ethiopia have uni-modal and others bimodal rainfall patterns.

Source: World Small Hydropower Development Report 2013.

The Ethiopian government has for long recognized that economic progress will depend principally on the development of the hydropower resources of the country. Ethiopia is endowed with abundant water resources distributed in many parts of the country however, it has not made significant progress in the field of water resources development during the past four decades. In particular, the exploitation of hydropower potentials was not noticeably successful in spite of being given priority as a major field of national development Considering the substantial hydropower resources, Ethiopia has one of the lowest levels of per capita electrical consumption in the world. Out of hydropower potential of about 15,000-30,000 MW, only about 360 MW (i.e. less than 2 percent) has been exploited by 1997 (Table 1).

Table 2: Hydropower Plants and Installed Capacity

Plant	System	Installed Capacity MW	Guaranteed Capacity MW	Energy Generation in GWH/year	Year of Commission
Finchaa HPP	ICS	100	100	616	1973
MelkaWakena HPP	ICS	153	148	434	1988
AwashII HPP	ICS	32	26	135	1966
AwashLII HPP	ICS	32	32	135	1974
Koka HPP	LCS	43.2	25	70	1960
TisAbbay I HPP	ICS	11.4	3.8	27	1964
Total ICS		371.6	334.8	1,417	
Yadot HPD	SCS	0.35	0.3,5	1.2	1990
Sor HPP	SCS	5	5	48	1990
Dembi HPP	SCS	0.8	0.8	2.8	1991
Total SCS		6.15	6.15	52	
Grand Total		377.75	340.95	1,469	

Presently, more than 90% of energy consumed in the country is derived from biomass fuels and is almost entirely used for cooking. The use of these fuels has resulted in massive deforestation and soil erosion. The population of Ethiopia was estimated in 1995 at 57 million and is thought to be growing at an annual rate of about 3.1%. In recent years, since the country has merged from the drought and civil war of the 1980's and since the implementation of a comprehensive program of economic reform, the economy has recuperated and is now growing. Such economic growth is essential to lift the people from severe poverty but can only be sustained by adequate infrastructures and in particular adequate supplies of electrical energy. The expected continued economic growth (in an environment of power shortage that had recently resulted in rationing) coupled with the rapid expansion of the transmission grid, will increase the number of consumers and thus the total energy demand in the next few years. This condition should evidently lead to an energy development program for accelerating the development process notably in the undertaking of studies and preparation of detailed engineering designs of hydropower projects that could be implemented within the shortest possible time. The major electric power planning and market survey study conducted so far had forecasted power and energy demand and supply to the year 2040. A 1993 forecast predicted the possibility of both power and energy shortages being very acute starting from 1995. The existing power generation in Ethiopia and the projected energy requirements from the .year 1990 through 2040 indicate and prove that the power generation needs to be increased by 4 times by the year 2000, more than 14 times by 2020 and about 25 times by 2040. To overcome the deficiency in electric power supply, in Ethiopia, special attention has, recently, been given by the government to Medium Scale Hydropower Development (MSHD) in the range of 40 MW to 60 MW capacities, (rather than Large Scale Hydropower Development Schemes). Experience has shown that the latter require huge investment, lengthy processes for securing finances as well as longer construction periods which might consequently not meet and fulfill the targeted demands for electricity in the different regions of the country within the shortest possible time. With this set goal, for surmounting the acute shortage in hydroelectric energy in Ethiopia, the government has given priority to the development of a number of favorably and fairly distributed hydropower resources. The rapid development of these schemes will definitely promote and speed up National and Regional developments at different and strategic river basins which is one of the government's program for harnessing the immense water resources potential of the major river basins of Ethiopia. Under the Ethiopian Government's Emergency Program, following the detailed reconnaissance studies, hydropower potential sites within Tekeze, Gojeb and Abbay River Basin had been identified and accordingly the selected sites, one in each basin, are now being looked into in detail in order to clear ground for effective implementation. The hydroelectric potential of Ethiopia is very considerable and is presented in Table 2. The total production of the above mentioned hydropower plants is 1,469.0 GWh/yr. (1994-1995).

Table 3: Hydropower Potential of Ethiopia

Name of River Basin	Number of Potential Sites				Technical Hydropower Potential (GWh/year)	Percentage Share of the Total %
	Small Scale 40 MW	Medium Scale 40-60 MW	Large Scale > 60 MW	Total		
Abbay	74	11	44	129	78,800	48.9
Rift Valley Lakes	7	-	1	8	800	0.5
Awas	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
Wabi 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	

Ethiopian Projects Identified for Power Development The Hydropower Potential of Ethiopia indicate

Ethiopia has a vast hydropower potential, which is estimated to be about 15,000 - 30,000 MW. So far very little percentage (less than 2%) of the vast potential has been harnessed. In order to develop this vast potential of power several projects have been initiated to generate more and more hydroelectric power. Some 300 hydropower plant sites in the whole eight river basins of the country with a total technical power potential of 159,300 Gwh/year have been identified. Out of these potential sites, 102 are large scale (more than 60 MW) and the rest are small (less than 40 MW) and medium scale (40-60 MW) hydropower plant sites (See Table 1.2).

Ethiopian Electricity sector overview After 2008

In 2009, 89 per cent of Ethiopia's population lived in rural areas and rural electrification was estimated at a mere 2-per cent (Gaul, 2010). The Government of Ethiopia launched its Rural Electrification Strategy in 2002 as a large governmental programme for electrification, consisting of three parts: grid extension by the public utility, Ethiopian Electric Power Corporation (EEPCo), private sector led off-grid electrification and promotion of new energy sources. The Rural Electrification Fund (REF) with its loan programmes for diesel-based and renewable energy based projects is the main implementing institution. With an initial budget of €29 million, REF has been supporting 180-200 rural micro-hydropower and photovoltaic (PV) mini-grids for educational and health care facilities (Hakizimana, 2009). The fund provides loans up to 95 per cent of investment needs with a zero interest rate for renewable energy projects. Renewable energy technologies that receive support under this programme include solar PV, mini- and micro-hydro, and biomass co-generation. According to EEPCo, the number of electrified towns and rural villages has increased significantly in the last five years of the strategic plan period. By July 2011 it had reached a total number of 5,866, bringing the country's electricity access to 46 per cent. In contrast, World Energy Outlook 2011 reported Ethiopia's 2009 national electrification access as 17 per cent (International Energy Agency (2011). This difference is probably due to the different reference points and sources. The EEPCo has two electricity supply systems: the Inter - Connected System (ICS) and the Self Contained System (SCS). The main energy source of

ICS is hydropower plants and for the SCS the main sources are mini hydropower schemes and diesel power generators allocated in various areas across the country are shown in the figure below.

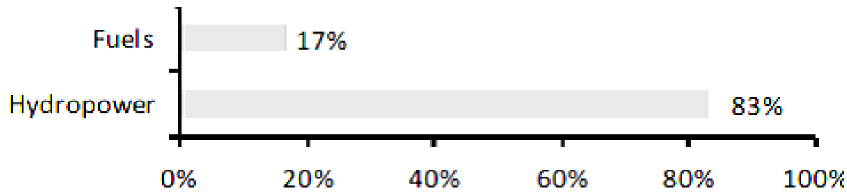

Figure 2: Electricity generation in Ethiopia

Source: Ministry of Energy and Mines

Small hydropower sector overview and potential In Ethiopia

According to a 2010-German Agency for Technical Cooperation Report, small- and micro-hydropower are not yet developed on a larger scale. Three small hydropower schemes exist in Yadot (0.35 MW), Dembi (0.8 MW) and Sor (5 MW) with a cumulative installed capacity of 6.15 MW (Shanko, Melessaw (2009, (figure).

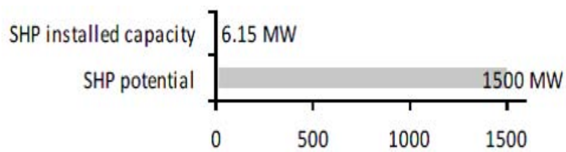

Figure 3: Small hydropower capacities in Ethiopia

Small rivers are being used to get people living in hard to reach areas on the electrical grid. three micro hydropower plants with a cumulative capacity of 125 kW were inaugurated in the villages of Ererte, Gobecho and Hagara Sodicha in Sidama zone in the Southern Nations, Nationalities and the Peoples' Regional State (SNNPR). The plants were implemented in partnership with Sidama Mines, Water and Energy Agency, the Sidama Development Association and local communities, and with the support of the Energy Coordination Office of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (Muluken Yewondwossen, 2012). Small rivers and waterfalls could generate electricity to energize many off-grid rural areas in Ethiopia. The Sor small hydropower plant has the potential to be expanded by an additional 5 MW. A feasibility study was undertaken in 1992 and another study conducted with the support of the United Nations Development Programme (UNDP) also calculated the same results, Ethiopia, Ministry of Water and Energy (2012). The Supervisory Review and Evaluation Process (SREP) Strategic Draft Report plans to implement this development between 2012 and 2014 by updating the existing feasibility study; design and tender document preparation; installation of additional penstock and additional 5 MW third unit, construction of a rock-fill dam, construction of annexed hydraulic structures (spillway, bottom out late and connection structure at the headrace tunnel) and finally refurbishment of the existing two units. As Exploer above, the government has given priority to the development of Medium Scale Hydropower potentials in the range of 40-60 MW in view of the urgency to fulfill the shortage of energy presently encountered, observed and experienced in the country. Typically, schemes of this size are considered to be more rapidly and easily brought to fruition as they require only modest investment and are likely to be appropriate for setting in rural areas to serve a number of communities. Any energy source that can 'be viably implemented in rural setting would contribute to the attractiveness of rural areas. Electric power would encourage the establishment of government offices and associated services in the more remote areas, improve the quality of educational, health and other services and enable individual rural households to have access to amenities which were formerly restricted to urban areas. The source of energy would also encourage the establishment of agro-processing and cottage industries, which would contribute to employment opportunities in rural areas. Nevertheless, since significant water resources are found in the rural areas, harnessing the power of falling water by means of small scale hydropower plants (less than 40 MW) as one way of providing affordable energy for the development of rural areas needs also to be looked into in detail along with the development of Medium Scale Hydropower Schemes and included in the top priority lists. Even if the the government has given priority to the development of Medium Scale Hydropowe potentials , but there is gap for the proper design, analysiss and the way to generate and impment the system. theis research work is conducted to design and analysis of Small Scale Hydropower. The research concerns to generate electric power From Small rivers and waterfalls could generate electricity to energize many off-grid rural areas in Ethiopia. in addition to this the power gereateted by constracting small dam or by the water water fill with two Continaeres and circulating them, and then to generet Power. It is, therefore, in the next topic concerns the detail design and analysis of generating small hydro power for rular electrifications, so as to allow private individuals to be free in generating and selling electric power generated by small scale hydropower plants in rular cumminity in the country .

b) Components of Hydro System

A complete hydro power system consists of the following major components, which are discussed in this section.

- Water storage and Water filtering mechanism
- Penstock with valves
- Turbine
- Power-converting device (Generator or direct-drive)

i. Generating Power

In nature, energy cannot be created or destroyed, but its form can change. In generating electricity, no new energy is created. Actually one form of energy is converted to another form of diesel power to generate electricity, water must be in motion. This is kinetic (moving) energy, when flowing water turns blades in a turbine, the form is changed to mechanical (machine) energy. The turbine turns the generator rotor which then converts this mechanical energy into energy form electricity. Since water is the initial source of energy, we call this hydroelectric power or hydropower.

ii. Water Filtering

A major aspect of system design that often is not considered is the removal of solid bodies from the water before it enters the turbine. If no such system is installed the turbine could suffer damage from sticks and stones, as well as reduced performance from leaves that get stuck on the blades. As this can never be totally removed the turbine will probably require cleaning at some stage for this design. There are several technologies available in order to stop these solid bodies from damaging the turbine or reducing its performance. A slanted box may be used in order to remove any surface material and then the outlet pipe may be situated higher than the bottom of the box so that any rocks are also removed, [BH Teuteberg March, 2010]

iii. Penstock

Following on the intake a length of pipeline is needed to direct the water to the turbine. Depending on the pressure in the pipeline it may be made of PVC or one of many other alternatives. The material should be appropriate to the application, which may in some cases be seawater. The pipe should also be strong enough to withstand the water pressure caused by the change in head.

The diameter of the pipe should be chosen so as to minimize friction losses without inflating the cost. [BH Teuteberg March, 2010]

iv. Hydraulic Turbines Classification by Principle of Operation

Hydraulic turbines extract energy from water which has a high head. There are basically two types, reaction and impulse, the difference being in the manner of head conversion. In reaction turbines the water fills the blade passages and the head change or pressure drop occurs within the impeller. They can be of radial, axial or mixed flow types. In impulse turbines the high head is first converted through a nozzle into a high velocity jet which strikes the blades at one position as they pass by. Reaction turbines are smaller because water fills all the blades at one time in short

a. Reaction Turbines

Reaction turbines are low-head, high-flow devices. The flow is opposite to that in a pump (from volute to eye of impeller after transferring most of the energy of the water to the impeller) but a difference is the important role stationary guide vanes play. Purely radial and mixed flow designs are called Francis turbines. At even lower heads an axial flow, propeller turbine is more compact. It can be fixed bladed but better efficiency is obtained over an operating range by using adjust ble vanes, in the Kaplan turbine.

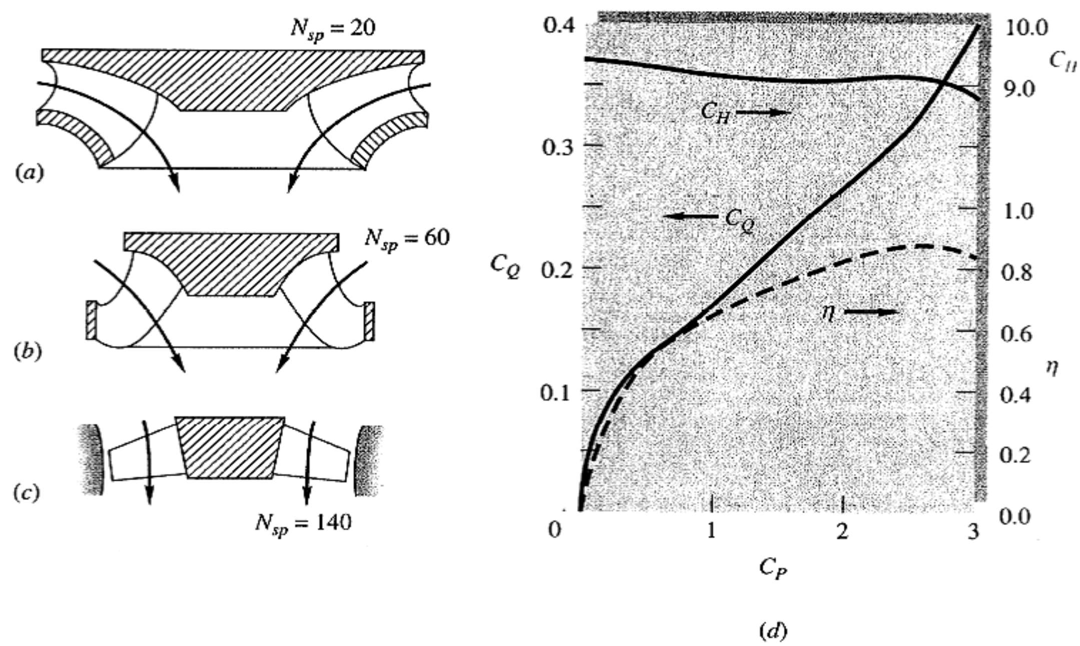

Fig. 4: Reaction turbines: (a) Francis, radial type; (b) Francis, mixed-flow; (c) propeller axial-flow; (d) performance curves for a Francis turbine, n = 600 rpm, D = 0.686 m, Nsp = 29 .

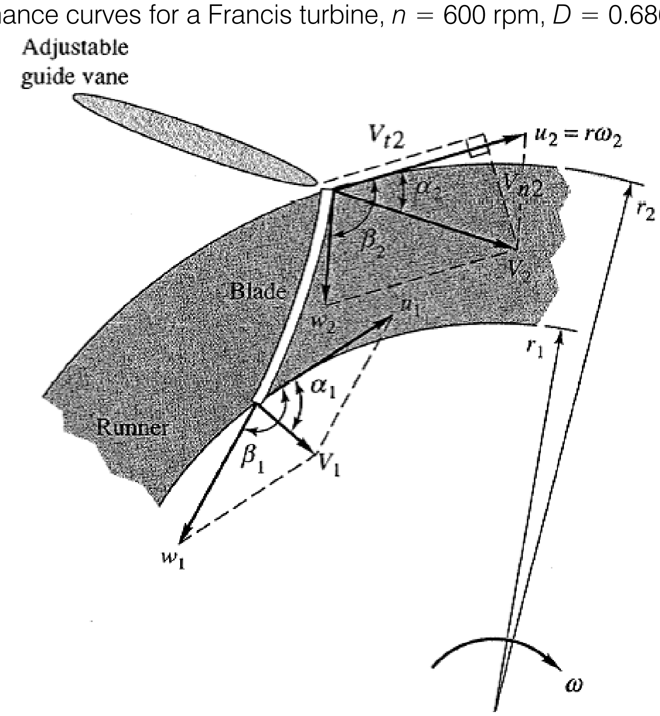

Fig. 5: Inlet and outlet velocity diagrams for an idealised radial-flow reaction turbine runner.

b. Impulse Turbines

For high head (typically above 250 m) and relatively low power (i.e. low *Nsp* from (10.2)) not only would a reaction turbine require too high a speed but also the high pressure in the runner would require a massive casing thickness. The impulse turbine in Fig. 10.3 is ideal for this situation. Since *Nsp* is low, *n* will be low and the high pressure is confined to the small nozzle which converts the head to an atmospheric pressure jet of high velocity *Vj*. The jet strikes the buckets and imparts a momentum change. The buckets have an elliptic split-cup shape and are called Pe ton wheels [Adam Harvey, MicrohydroDesign Manual].

Table 4: Various heads of turbines

Turbine type	Head range in meter
pelton	50 to 1770
Francis	10 to 350
Turgo	50 to 250
Kaplan and propeller	2 to 40
Cross flow(Michell-Banki)	3 to 250

Table 5: Specific speed(source S. Khurana2011)

Turbine	Specific speed
pelton	8.5 to 47
Turgo	30 to 85
Cross flow	20 to 200
Francis	85 to 188

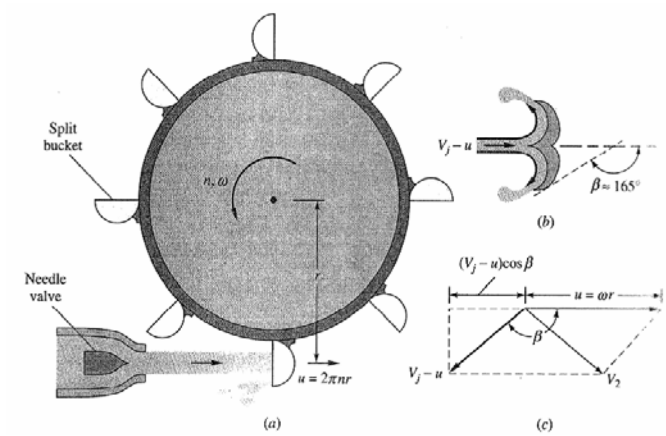

Fig. 6: Impulse turbine: (a) side view of wheel and jet; (b) top view of bucket; (c) typical velocity diagram

Hydro Turbine Electrical System

Hydro-turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, or other machinery to produce electrical power. The conversion process involves two main steps:

- The fluid dynamic power available in the water is first converted in to mechanical power

- The available mechanical power is then converted into electrical power. The power available is proportional to the product of pressure head and volume flow rate. The general formula for any hydro system's power output is: where *P* is the mechanical power produced at the turbine shaft (Watts), η is the hydraulic efficiency of the turbine, ρ is the density of water (kg/m3), *g* is the acceleration due to gravity (m/s^2), *Q* is the volume flow rate passing through the turbine (m^3/s), and *H* is the effective pressure head of water across the turbine (*m*). Water is taken from the river by diverting it through an intake at a container. The container is a main barrier which maintains a continuous flow through the intake. A turbine converts the energy from falling water into rotating shaft power.

III. Design and Analysis

Hydro System Components

Energy Consumption Estimate of Rural Community

Electricity consumption shows large variations depending on climate, culture, reliability of supply, and location. Generally, rural households in developing countries such as Ethiopia have very low electricity consumption, with the primary uses being for lighting and operation of radios, and televisions. In Ethiopa, official definition of a rural community is one with a population less than 10,000 [3], with an assumed average household of 10. An average energy demand estimate, E in kWh, of a given household within a rural setting may be computed using the energy equation described by (Igbinovia, (2007). Where P_r is the wattage rating of a given household appliance (component) in kilowatt (kW), t- is the duration for which the appliance is to be operated in hours (h), n is the number of the appliance. The energy demand estimate has been expressed in kWh because it is fundamental unit in which quantity of electricity (electric energy) used is measured. One kilowatt-hour is equivalent the amount of work done by one kilowatt of electric power in one hour. Hence, in a rural household where lighting is the only primary use of electricity, for instance, six 60-watt incandescent lamps used for about five hours each night will have a daily consumption of 1.8 kWh based on equation (1). A radio set and a small fan of wattage ratings 20 W and 50 W respectively can be used for 10 hours each day for an additional consumption of 0.2 to 0.5 kWh. A small TV set of wattage rating used for 6 hours a day will add a further 0.72 kWh. A family could accommodate all these uses easily within a consumption range of 4 kWh daily. Adejumobi et al. [Oliver Paish, 2002] in their work using Nigeria as a case study estimated the energy needed by typical rural/remote environment ICT infrastructures, banking and hospital services. These results revealed that for a typical rural/remote environment as it is applicable in Nigeria because the definition of a rural community varies from communities to communities across different countries of the world, the total weekly hour energy consumptions of ICT infrastructures, banking and hospital services could respectively be in the range of 48.836kWh, 72.908kWh and 12.660kWh equivalent to a daily average of 6.976 kWh, 10.415 kWh and 1.809 kWh respectively (Adejumobi I.A.).

a) Water Diversion(Intake)

The intake is typically the highest point of a hydro system, where water is diverted from the stream into the pipeline that feeds the turbine. A water diversion system serves two purposes: provide a pool of water to create an air- free inlet to the pipeline, an d remove dirt and debris [H 2, H5]. See Figure 8.1. Diversion System refers to the means used to divert water from the source and transport it to your turbine. There are various methods for diverting and transporting the water, bu t diversion systems can be grouped into two basic types: Open and Closed systems. Matchi ng the correct type of diversion system to a particular style of micro hydro turbin e is critical to the optimal performance of the turbine. In general, impulse turbines (which produce power primarily from head pressure) will utilize a closed diversion system. Reaction turbines (which produce power primarily from water volume) will normally work best with an open diversion system.

i. *Closed Diversion Systems*

In a closed diversion system (such as a pi pe), the system is sealed and water is isolated from direct gravitational forces while in the pipe. The water surface at the inlet to the pipe is the point at which gravity directly affects the water, and is, therefore, the starting elevation for the system head. Closed diversion systems work well for developing high pressure head with relatively low water flow volumes [H11].

ii. Pen Diversion Systems

In an open diversion system (such as a canal), the water along the entire diversion system is directly exposed to gravity. In an open diversion system, then, the last point at which gravity directly impacts the water is the water surface directly above the turbine **inlet**. Thus, the starting elevation for the pressure head is often the water surface directly above the turbine. The ending point for pressure head is the turbine impeller. Open diversion systems work well for supplying large volumes of water to the turbine with low friction losses [H11].

b) Pipeline (Penstock)

The pipeline, or penstock, not only moves the water to the turbine, but is also the enclosure that creates head pressure as the vertical drop increases. The pipeline focuses all the water power at the bottom of the pipe, where the turbine is. In contrast, an open stream dissipates the energy as the water travels downhill [H6]. One or more bypass valves may be necessary. These should be installed at low points in the pipe to help get the flow going and to flush out air bubbles. Figure 8.6 shows an example of the location of a pipeline relative to point of use.

c) The Head of hydro power

Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. In this case the energy extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. This height difference is called the head. The amount of potential energy in water is proportional to the head [H1, H2]. To obtain very high head, water for a hydraulic turbine may be run through a large pipe called a penstock, see Figure 8.1.

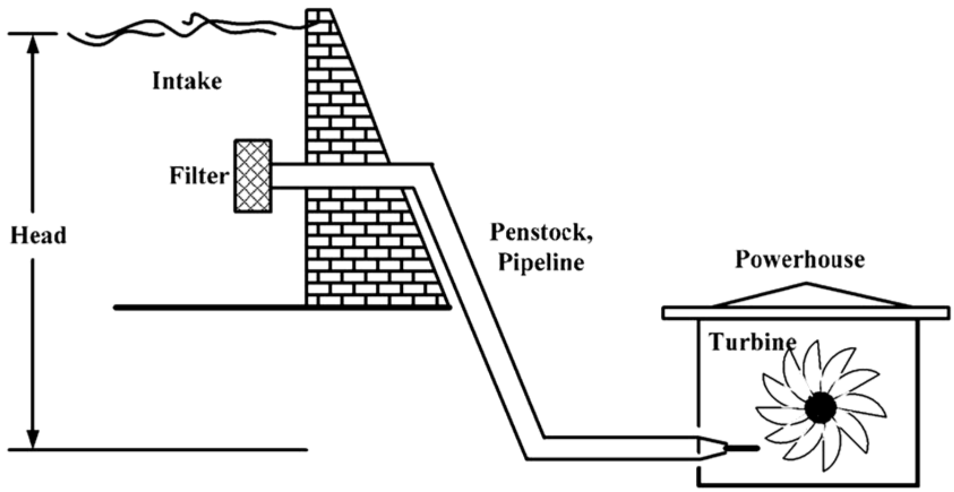

Figure 7: Hydroelectric power generation diagram

Based on the head of hydro power is the one based on the height of head. The height of the head is almost similar with the height of the dam used in the hydro electric power. There are three common types of hydro power based on the head level (High head (>100m), Medium head (50-100m), Low head (~20m) [P. Cunningham, 2007]. The following Figure shows the pictures for low, medium and high head hydro power. The height of head will also affect the choice of turbine type selected. Based on the picture, the low head does not seem to use dam, even it uses small dam (called barrage in the picture), meanwhile the medium and high head hydro power are using dam., the higher head means more installed capacity, which is defining the size of hydro power.

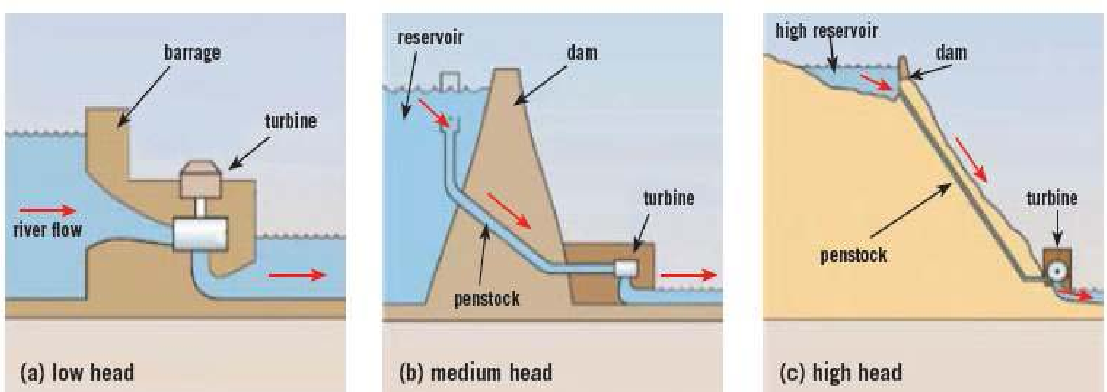

Figure 8: Three common types of hydro power plants based on the head level(low, medium and high head hydro power).

For a volume of a fluid which is not in motion or is in a state of constant motion, Newton's Laws states that it must have zero net force on it - the forces going up must equal the forces going down. This force balance is called the hydrostatic balance. The net force over one point is due to the fluid weight [H9]. In Figure 8.2 we can see the linear variation of pressure by water height, and then the basic hydrostatic equationis:

$$P = P_0 + \gamma h \tag{8.2.1}$$

Where γ = Specific Weigh of the fluid (lb/ft^3),
P_0= Atmospheric pressure (lb/ ft^2),
h = Height (ft).

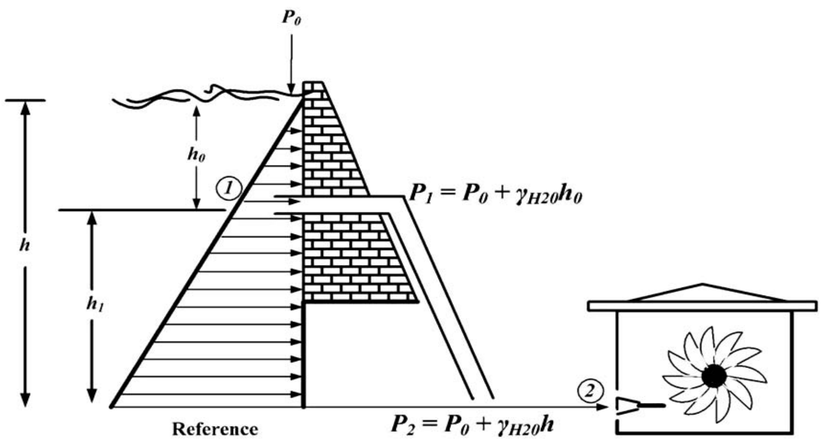

Figure 9: Variable Pressure by Water Height

To determine the hydraulic power we use the Conservation Energy Law which states that the energy can neither be created nor destroyed. This means that the total energy of a system remains constant. The total energy includes potential energy due to elevation and pressure and also kinetic energy due to velocity. Considering the system in the bove Figure, we can state that the total energy in point 1 is:

$$E_t = Wh_1 + W\frac{P_1}{\gamma} + \frac{1}{2}\frac{W}{g}v_1^2 = cons\tan t$$

$$E_t = Wh_1 + W\frac{P_1}{\gamma} + \frac{1}{2}\frac{W}{g}v_1^2 - H_t = Wh_2 + W\frac{P_2}{\gamma} + \frac{1}{2}\frac{W}{g}v_2^2$$

Where V1, V2 = velocities at point 1 and 2 respectively (ft/s), H1= Represents losses in pipe (ft). From Equation 8.2.3 we determine that the velocity at the intake of the system point 1 is the same as the velocity in point 2, but not necessarily the same at the turbine input. This is due to the use of nozzles at the pipe end in some cases. The Continuity Equation states that for steady flow in a pipeli ne, the weight flow rate (weight of fluid passing a given station per unit time) is the same for all locations of the pipe [H9, H10]. To illustrate the significance of the continuity equation, refer to Figure 8.3, which shows a pipe in which fluid is flowing with a weight flow rate W that has units of weight per unit time. The pipe has two different-size cross-sectional areas identified by stations 1 and 2. The continuity equation states that if no fluid is added or withdrawn from the pipeline between stations 1 and 2, then the weight flow rate at stations 1 and 2 must be equal.

$$w_1 = w_2 \tag{8.2.4}$$

$$yA_1v_1 = yA_2v_2 \tag{8.2.5}$$

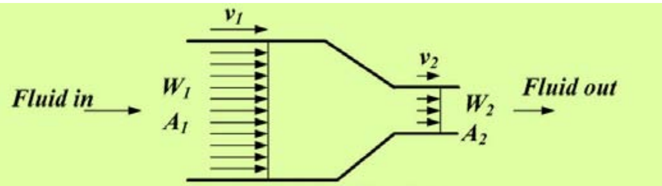

Figure 8.3. Continuity of Water Flow.

Where γ = Specific Weigh of the fluid (lb/ft^3),
A = Cross-sectional area pipe (ft^2),
v = Velocity of fluid (ft/s).

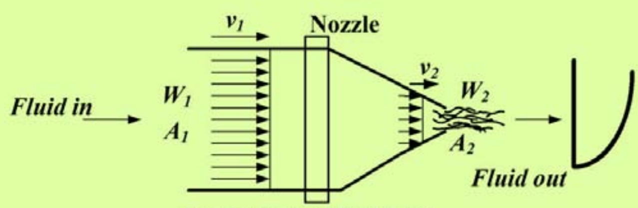

Figure 8.4. Nozzle Velocity Variations.

Once we have determined the velocity at point 1 in Figure 4, applying Equation 5 we find the velocity at point 2, then we know,

$$F = P(lb/ft^2).A(ft^2)$$
$$energy = F(lb).l(ft) = PAl$$
$$Power = \frac{energy}{time} = \frac{PAl}{t} = PAv$$
$$Caudal(Q) = Av,$$
$$HydraulicPower(ft.lb/s) = P(lb/ft^2).Q(ft^3/s)$$
$$HydraulicHousepower = HHP = P(lb/ft^2).Q(ft^3/s).\frac{1hp}{550\,ft.lb/s} \qquad (8.2.6)$$

i. *Net Hea*

Net head is the pressure at the bottom of the pipeline when water is actually flowing to the turbine. This will always be less than the gross head measured, due to friction losses within the pipeline. Water flow figures are needed to compute net head. Longer pipelines, smaller diameters, and higher flows create greater friction. A properly designed pipeline will have a net head of 85 to 90 percent of the gross head measured.

ii. *Flow Measure*

The second major step in evaluating a site's hydro potential is measuring the flow of the stream. Stream levels change through the seasons, so it is important to measure flow at various times of the year. The use of the stream by wildlife and plants must also be considered. Applicable permits should be sought from local agencies overseeing natural resources and wildlife preservation. Never use all of the stream's water for your hydro system [H3]. Flow is typically expressed as volume per second or minute. Common examples are gallons or liters per second (or minute), and cubic feet or cubic meters per second (or minute).Three popular methods are used for measuring flow: container, float, and weir. The container fill method is the most common method for determining flow in micro hydro systems. Identify a spot in the stream where all the water can be caught in a bucket. If this is not possible, a temporary dam can be built that forces all of the water to flow through a single outlet. Using a bucket or larger container of a known volume, use a stopwatch to time how long it takes to fill the container [H3]. With the Net Head and Flow measurements one can determine the power output of a stream engine, as shown in The following Table shows. Higher head and flow bring out more power; however a right selection of the turbine is the critical stage of de design process and will determine the output capacity.

Table 7: Output Power (Watts) of Stream Engine [H5].

	Flow Rate (Liters per second)						
Net Head (m)	**0.67**	**1.33**	**2.50**	**5.00**	**6.67**	**7.50**	**9.50**
3		20	50	90	120	130	150
6	15	40	100	180	230	250	350
15	45	110	230	450	600	650	800
30	80	200	500	940	1100		
60	150	400	900	1500			
90	200	550	1200				
120	300	700	1500				
150	400	850	1900				

d) Turbine designs

i. *Material Selection*

a. *General*

The material qualification is at least to include:

- Requirements for repeatability of manufacturing processes
- Requirements for traceability of materials (e.g. name and trademark of manufacturer, material grade, batch number)
- Requirements for material storage (e.g. control of temperature, humidity and shelf life)
- Characteristic material parameters for all relevant limit states including: minimum and maximum service temperatures, and other environmental conditions (e.g., strength, toughness, density, cold deformability, ageing characteristics, resistance to rot and sun light)
- The material qualification shall cover changes in material properties over the range of service temperatures such as embrittlement at low temperatures and drastic changes near the glass transition temperature for the materials.
- The embrittlement may typically not influence stiffness or strength for the material without imperfections. The embrittlement may have a drastic impact on the sensitivity to imperfections.
- purchase specifications for the individual materials. the specifications shall as a minimum cover/cost: s

ii. *Design of Cross-Flow Turbine for Small Hydro-Power*

Hydro-power was considered as one of the most desirable source of electrical energy due to its environmental friendly nature and extensive potential available throughout the world. Within the scope of hydro-electric power, small power plants have gained much attention in recent years. Several small hydro-power schemes have been proposed and successfully implemented, which include radial, axial, and propeller type turbines.

iii. *Design steps for turbine*

a. *Turbine Runner*

The runner is the heart of the turbine. This is where water power is transformed into the rotational force that drives the generator. Regardless of the runner type, its buckets or blades are responsible for capturing the most possible energy from the water. The curvature of each surface, front and rear, determines how the water will push its way around until it falls away. Also keep in mind that any given runner will perform most efficiently at a specific Head and Flow. The runner should be closely matched to your site characteristics. Quality components and careful machining make a big difference in turbine efficiency and reliability. Look for all-metal runners with smooth, polished surfaces to eliminate water and air turbulence. One- piece, carefully machined runners typically run mo re efficiently and reliably than those that are bolted together. Bronze manganese runners work well for small systems with clean water and Heads up to about 500 feet. High-tensile stainless steel runners are excellent for larger systems or abrasive water conditions. All runners should be carefully balanced to minimize vibration, a problem that not only affects efficiency but can also cause damage over time.

b. *The design procedure of the cross-flow turbine involves the following steps*

1. Preparing the site data This involves the calculations and measuring the net head of the hydro-power plant and its water flow rate.

- Calculation of the net head (*Hn*)

$$Hn = (Hg - Htl)\ in\ metter$$

Where Hg = the gross head which was the vertical distance between water surface level at the intake and at the turbine. This distance can be measured by modern electronic digital levels.

Htl = total head losses due to the open channel, trash rack, intake, penstock and gate or value. These losses were approximately equal to 6% of gross head.

- the potential energy of the water calculate using the formula PE=mgh
- Calculate the water's final velocity just before hitting the turbine blades using, PE= KE=1/2mv^2

From this Equation V=(2gh)$^{1/2}$

- Calculation of the water flow rate (*Q*): The water flow rate can be calculated by measuring river or stream flow velocity (*Vr*) and river cross-sectional area (*Ar*), then:

$$Q = Vr * Ar\ (\mathrm{m}^3/s$$

2. Calculation of turbine power (*Pt*) The electrical power of the turbine in *Watt* can be calculated as $Pt = \rho * g\eta t * Hn * Q\ (watt)$

The output power available in a stream of water is;
P=rηghQ
P = power (J/s or watts)
η = turbine efficiency
ρ = density of water (kg/m3)
g = acceleration of gravity (9.81 m/s2),
h = head (m).

For still water, this is the difference in height between the inlet and outlet surfaces. Moving water has an additional component added to account for the kinetic energy of the flow. The total head equals the pressure head plus velocity head, Q= flow rate (m^3/s).

3. Calculation of turbine efficiency (*ηt*) The maximum turbine efficiency can be calculated as

$$\eta = \frac{1}{2} * C^2 * (1+\psi) * cos^2(\alpha) \qquad (4)$$

From equation (4) above, its clear that the attack angle (α) should be kept as small as possible for maximum turbine efficiency. The manufacturing of this type of turbine has shown that arc angle of (16°) can be obtained without much inconvenience.

4. Calculation of the turbine speed (*N*): The correlation between specific speed (*Ns*) and net head is given for the cross-flow turbine as :

$$N_s = 513.25 / H_n^{0.505} \qquad (5)$$

Also the specific speed interms of turbine power in Kw, turbine speed in (r.p.m) and net head in (m) is given as

$$N_s = N * \sqrt{P_t} / H_n^{5/4} \qquad (6)$$

From equations (5) and (6) above, the turbine/runner speed can be calculated as:

$$N = 513.25 * H_n^{0.745} / \sqrt{P_t} \quad (r.p.m) \qquad (7)$$

5. Calculation of runner outer diameter (*Do*) At maximum efficiency, the tangential velocity of the runner outer periphery is given as

$$V_{tr} = \frac{1}{2} * C * \sqrt{2*g*H_n} * \cos(\alpha) \qquad (8)$$

Also

$$V_{tr} = w * \frac{D_o}{2} = \frac{2\pi N D_o}{120} \qquad (9)$$

From equations (8) and (9) the runner outer diameter can be calculated as:

$$D_o = 40 * \sqrt{H_n} / N \quad (m) \qquad (10)$$

6. Calculation of blade spacing (*tb*): The thickness of jet entrance (*te*) measured at right angles to the tangential velocity of runner is given as

$$t_e = K * D_o \quad (m) \qquad (11)$$

Where *K* = constant = 0.087, the tangential spacing (*tb*) is given as

$$t_b = t_e / \sin(\beta_1) = K * D_o / \sin(\beta_1) \qquad (12)$$

Where *β1* = blade inlet angle = 30° when α = 16°. Then

$$t_b = 0.174 * D_o \qquad (13)$$

7. Calculation of the radial rim width (*a*): It is the difference between the outer radius (*ro*) and inner radius (*ri*) of the turbine runner, and it is also equal to the blade spacing and can be given as:

$$a = 0.174 * D_o \quad (m) \qquad (14)$$

8. Calculation of the runner blade number (*n*) The number of the runner blades can be determined as

$$n = \pi * D_o / t_b$$

9. Calculation of the water jet thickness (*tj*) It is also defined as nozzle width and can be calculated as

$$t_j = A_j / L = \frac{Q/V_j}{L} = Q / (C * \sqrt{2*g*H_n} * L) = 0.233 * Q / (L * \sqrt{H_n}) \qquad (16)$$

Where Aj = jet area (m2).

10. Calculation of runner length (L): The runner length in (m) can be calculated as: From reference

$$L * D_o = 210 * Q / \sqrt{H_n} \qquad (17)$$

By transforming the British units of equation (17) above into metric units, it can be obtained as:

$$L * D_o = 0.81 * Q / \sqrt{H_n} \qquad (18)$$

Substitute equation (10) into (18) to obtain

$$L = Q * N / (50 * H_n) \quad (m) \qquad (19)$$

Substitute equation (19) into (16) to obtain:

$$t_j = 11.7 * \sqrt{H_n} / N \qquad (20)$$

Also substitute equation (10) into (20) to obtain the jet thickness at maximum efficiency as:

$$t_j = 0.29 * D_o \qquad (m) \tag{21}$$

11. Calculation the distance between water jet and the center of runner shaft (*y1*) [2]:

$$y_1 = 0.116 * D_o \tag{22}$$

12. Calculation the distance between water jet and the inner periphery of runner (*y2*) [2]

$$y_2 = 0.05 * D_o \tag{23}$$

13. Calculation inner diameter of the runner (*Di*)

$$D_i = D_n - 2 * a \tag{24}$$

14. Calculation of the radius blade curvature (*rc*)

$$r_c = 0.163 * D_o \tag{25}$$

15. Calculation of the blade inlet and exit angles (b*1*and b2)[2]: The blade inlet angles can be calculated as

$$\tan(\beta_1) = 2 * \tan(\alpha) \tag{26}$$

The blade exit angle *2* = 90° for perfect radial flow, but it must be equal to (*1*) at maximum efficiency.

16. The difference in elevation between the turbine and the upper reservoir is called the "head". Any losses in the pipe due to friction or viscosity are converted into an equivalent form and when subtracted from the head the result represents the "net available head". The losses are normally expressed in terms of a head loss Coefficient

$$h_{loss} = k\left(\frac{v^2}{2g}\right)$$

The first head loss that is considered is friction losses in the pipe. The friction factor is highly dependent on the Reynolds number of the flow,

$Re = \frac{dv}{\nu}$, If the Reynolds number is below 2100 it can be assumed that laminar flow is occurring, in which case the friction factor is simply:

$f = \frac{64}{Re}$, If the Reynolds number is above this value there is a transitional period where it is not certain whether fully laminar or turbulent flow is occurring. In this case turbulent flow is assumed and the applicable equation is:

$$f = \frac{1.325}{\left(\log\left(\frac{\frac{e}{d}}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right)^2}$$

In this equation the pipe roughness factor (e) is required. In The following Table

Table 8: Values of pipe roughness for various materials

Material	e(mm)
Drawn tubing, brass, lead, glass, bituminous lining	0.0015
Commerical Steel or Wrought Iron	0.046
Welded Steel pipe	0.046
Galvanized Iron	0.15
Concrete	0.3-3
Riveted Steel	0.9-9

When the friction factor is know it is simple to calculate the friction head loss coefficient using equation

$$k_{friction} = f\left(\frac{L}{D}\right)$$

There are also certain losses that occur at the pipe entrance. The losses occur as a result of the contraction and subsequent expansion of water stream lines flowing into the pipe section. Some commonly encountered pipe sections also induce losses in the system.

Table 9: Head loss coefficient for various pipe segments

Fitting	$K_{sections}$
Gate Valve (wide open)	0.19
Gate Valve (half open)	2.06
Long radius bend	0.6
Short radius bend	0.9
T(through side outlet)	1.8
Smoothly curved contraction	0.05

The total head loss can now easily be calculated by using the head loss coefficient for each entrance, pipe section and pipe material.

$$h_l = \left(\sum k_{friction} + \sum k_{entrance} + \sum k_{sections}\right)\left(\frac{v^2}{2g}\right)$$

e) Drive System

The drive system couples the turbine to the generator. At one end, it allows the turbine to spin at the velocity that delivers the best efficiency. At the other end, it drives the generator at the velocity that produces correct voltage and frequency (frequency applies to alternating current systems only). The most efficient and reliable drive system is a direct, 1 to 1 coupling between the turbine and generator. This is possible for many sites, but not for all head and flow combinations. In many situations, especially with AC systems, it is necessary to adjust the transfer ratio so that both turbine and gene rator run at their optimum (but different) speeds. These types of drive systems can use gears, chains, or belts, each of which introduces additional efficiency losses into the system. Belt systems tend to be more popular because of their lower cost [H2].

i. Generator

Typically in hydro systems the torque from the output shaft of the turbine is converted into electricity by use of a generator. This provides great flexibility for the use of the power as the electricity is easy to transport and use for multiple devices at the same time. In converting the energy from the shaft into electricity some energy is lost. As the power from the turbine may be used to drive a pump, there will again be losses when the electricity is used in the pump motor. Generator performance is comparable to motor performance and thus the range of typical total efficiencies for just the electrical sub-system would be between 50% and 92%. The efficiency of the motor is also relative to the load as motors running at partial load will be less efficient. It is thus crucial to choose the correct size for the motor and therefore also the generator.

ii. Direct Drive Pump

The losses experienced in the generation and use of electricity may be avoided by connecting the shafts of the Turbine and the pump. This means that most of the power generated in the turbine will reach the pump, with small losses experienced in possible clutches and gearboxes. However, a major negative aspect of this solution is that the location of the turbine system becomes more constrained as it needs to be situated next to the pump it would power. This solution should be more efficient than a generator when powering a single constant load such as a pump which runs all the time. As soon as multiple or variable loads are to be powered by the turbine system a generator may prove to be a simpler and more effective solution.[BH Teuteberg March, 2010]

Table 10: Differences between generators and direct drive systems

	Generator	Direct Drive Pump
Advantages	Produces electricity which can be used in various areas	Much higher total efficiency
	Can be purchased as a commercial package with the turbine/PAT	Simpler design, requires fewer components
	The reliability of the turbine/PAT will not affect the flow of water	Cheaper, if existing pumps can be driven
Disadvantages	Energy is lost in the generator	Pump has to run at same rotational speed as turbine/PAT or gearbox is required
	Requires a complex electrical regulating system with a dump load	Operation of system is dependent on reliability of both turbine/PAT and the Pump.
	More expensive	The PAT/turbine has to be situated next to the pump

f) Small Hydro turbine System Design

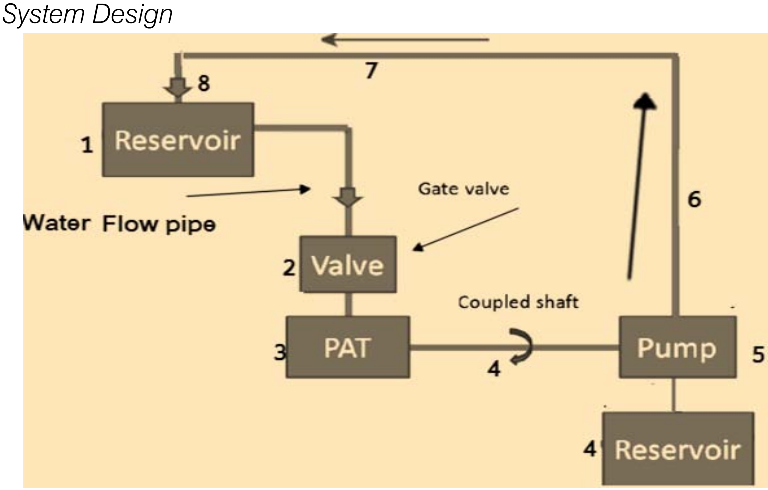

Figure 10: Schematic of systeme

Operation procedure of Small Hydro turbine

The generator in the system is the mechanical-electrical converter in the water turbine and the gearbox and rotor blades need to be designed to supply the motor with an input that will yield the desired output power. This being said, a suitable motor first needs to be selected and tested to determine the input speed required to produce 1- 5 kW before any other design goes ahead. Once this has been determined a rotor system and gearbox can be designed to produce the required revolution speed and torque to supply mechanical power to the motor. In selecting a motor consideration needs to be made as to what type of current is being produced and where it will flow to, if it will be stored or if it will be directly applied in an electrical device and water pump. After connecting the motor shaft with water pump, the pump lift out water from lower container to deliver the upper water tanker and then the water is circulating. the motor shaft is used as an input for water pump and at the same time it generating power.

Case-1, Reservoir Tanker-Valve/pipe PAT-Motor-Gear Box/Mechanism-Water pump and also posible

Case-2, Reservoir Tanker-Valve/pipe PAT- Gear Box/Mechanism- Motor- -Water pump

IV. Results

In this study, the design and Analysis of small -hydro-electric power for rural electrification is done, the theoretical electric power generating potential and capacities for container (run-of-river) the systems are developed. Following the standard small hydropower guide and past works are included, the turbine and generator efficiencies are selected and designed. This design and Analysis of small -hydro-electric power is done using mathematical and Numerical (Matlab) methods is applied. After introducing the site measurements and calculations as input data to the computer program, the weir dimensions, open channel dimensions, penstock dimensions, turbine type, turbine size, turbine power, turbine speed, turbine efficiency, generator specifications and gear box ratio are determined. Figures (3, 4) show the relation between turbine power and speed with gross head at different values of water flow rate. Figures (5, 6) show the variation of turbine power and speed with water flow rate at different values of head. From these results, the turbine power and speed were directly proportional with the gross head, but there were specific points for maximum power and maximum speed in case of water flow variation. Figures (7, 8) show the variation of head loss with the gross head and water flow rate. It can be shown that the head loss was increased very high with increasing the water flow rate than that with increasing the gross head.

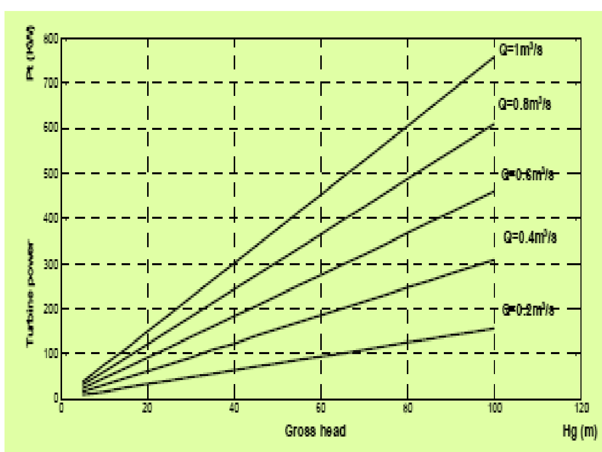

Figure 11: Variation of turbine power with gross head at different values of water flow rate

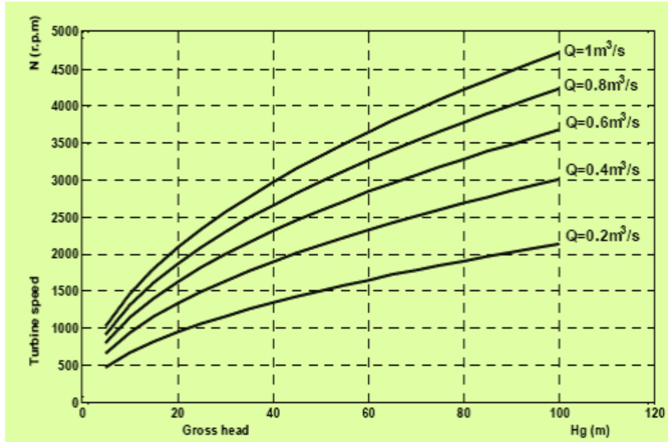

Figure 12: Variation of turbine speed with gross head at different values of water flow rate

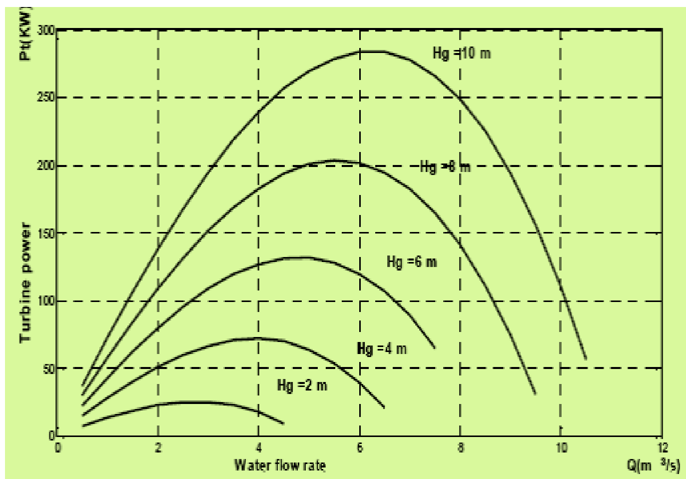

Figure 13: Variation of turbine power with water flow rate at different values of gross head

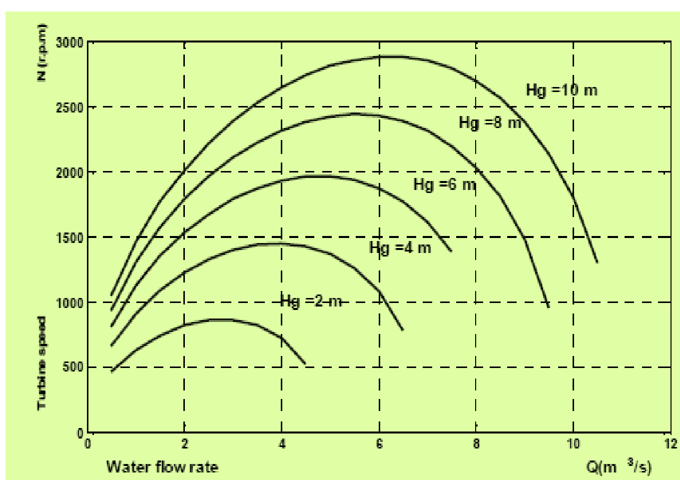

Figure 14: Variation of turbine speed with water flow rate at different values of gross head

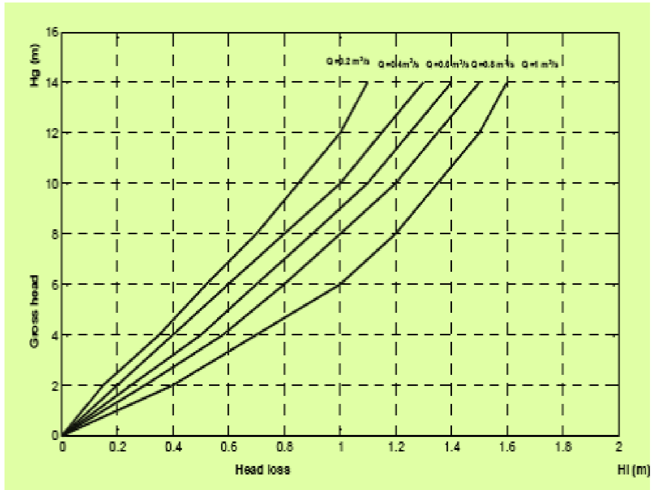

Figure 15: Variation of gross head with head loss at different values of water flow rate

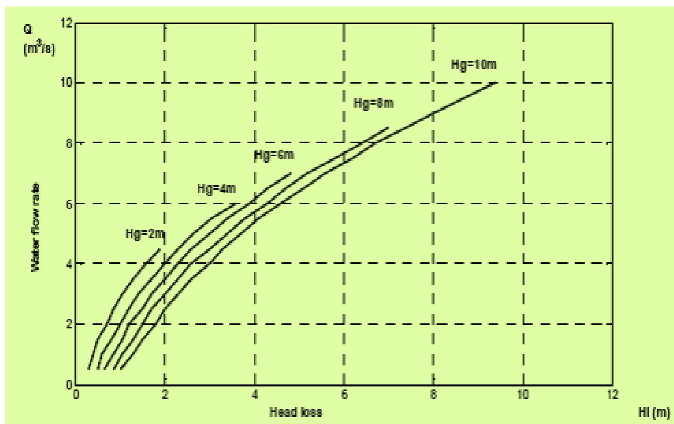

Figure 16: Variation of water flow rate with head loss at different values of gross head

V. Conclusions

Hydropower, large and small, remains by far the most important of the "renewables" for electrical power production worldwide. Small-scale hydro is in most cases "run-of-river", with no dam, and is one of the most cost-effective and environmentally benign energy technologies to be considered both for rural electrification in less developed countries and developed countries for further hydro developments. The cross-flow turbine is suitable for installing small hydro-electric power plants in case of low head and flow rate. A complete design of such turbines has been presented in this paper. The complete design parameters such as, Trbine material, runner diameter, runner length, water jet thickness, blade spacing, radius of blade curvature, turbine power, turbine speed, number of blades, and any losses in the pipe due to friction, were determined at maximum turbine efficiency.

i. Small-hydro power continues to grow around the world, it is important to show the public how feasible small-hydro systems actually are in a suitable site. The only requirements for small-hydro power are water sources, turbines, generators, proper design and installation, which not only helps each individual person but also helps the world and environment as a whole.
ii. Run-of-river or containwer small-hydro turbine schemes generate electricity when the water is available and provided by the continer . When the container dries-up and the flow falls below predetermined amount or the minimum technical flow for the turbine, generation will ceases.
iii. Medium and high head schemes use Weirs to divert water to the intake, it is then conveyed to the turbines via a pressure pipe or penstock. Penstocks are expensive and the design is usually uneconomic due to the high penstock friction head loss. An alternative is toconvey the water by a low-slope canal, running a long side the container or river to the pressure intake or forebay and then in a short penstock to the turbine.
iv. The choice of turbine will depend mainly on the pressure head available and the water flow rate. There are two basic modes of operation for hydro power turbines: Impulse and reaction. Impulse turbines are driven by a jet of water and they are suitable for high heads and low flow rates. Reaction

turbines run filled with water and use both angular and linear momentum of the flowing water to run the rotor and they are used for medium and low heads and high flow rate.

v. Regulated turbines can move their inlet guide vanes or runner blades in order to increase or reduce the amount of flow they draw. Cross-flow turbines are considered best for micro-hydro projects with a head of (5) meters or less and water flow rate (1.0) m3/s or less.

vi. Small-hydro power installations are usually run-of-river or container systems, which do not require a dam, and are installed on the water flow available on a year round basis. An intake structure with trash rack channels water via a pipe (Penstock) or conduit down to a turbine before the water released down-stream. In a high head (greater than 50 m) and low water flow (less than 0.5 m3/s), the turbine is typically Pelton type connected directly to a generator with control valve to regulate the flow of water and turbine speed.

References Références Referencias

1. O.Dzune Mipoung, Generator Requirements for Rural Electrification from Renewable Energy, 2002,
2. Bilal Abdullah Nasir February 2013 , Design of High Efficiency Cross-Flow Turbine for Hydro-Power Plant
3. kid wind project, 2013, Advanced Blade DesignBy O. Dzune Mipoung1 Generator Requirements for Rural Electrification from Renewable Energy
4. By BH Teuteberg March, 2010 ,Design of a Pump Microhydro System Pump-As-Turbine for an Abalone Farm.
5. Mockmore, C. A. and Merryfield, F.,1949."The Banki water turbine", Engineering Experiment Station Bulletin Series,
6. S. Khurana,2011, Small Hydro Power- A review
7. Small hydro power: technology and current status
8. Oliver Paish February 2002,IT Power Ltd, The Manor House, Chineham Court, Lutyens Close, Chineham, Hampshire
9. Fraenkel P, Paish O, Bokalders V, Harvey A, Brown A, , 1991.Edwards R. Micro-Hydro Power: a guide
10. for development workers. London:
11. P. Cunningham, I. Woofenden, "Microhydro-Electric Systems", Home Power 117, February & March 2007
12. Adejumobi, I.A. and Adebisi, O.I. (2011). Exploring Small Hydropower Potentials for Domestic and Information Communication Technology Infrastructural Application in Rural Communities in Nigeria. Proceeding of the 12th Biennial International Conference of Botswana Institution of Engineers, Gaborone, Botswana, pp.19-26.
13. Anyaka Boniface Onyemaechi, Small Hydropower Projects for Rural Electrification in Nigeria: A Developer's Perspective, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-3, Issue-5, October 2013
14. Igbinovia, S.O. and Orukpe, P.E. (2007). Rural Electrification: The Propelling force for Rural Development of Edo State, Nigeria. Journal of Energy in Southern Africa,
15. Simply Green: Coanda Power Systems for Small Hydro By Ryan Cook, Vice President, Cook Legacy, Columbus, Ohio,2012
16. Kari Sørnes, ZERO – Zero Emission Resource Organization ,January 2010
17. World Small Hydropower Development Report 2013
18. Ethiopia, Ministry of Water and Energy (2012). Scaling-Up Renewable Energy Programme
19. Ethiopia Electric Power Corporation (2012). Existing Power Plants Database. Available from www.eepco.gov.et/generation_op.php. Accessed December 2012.
20. International Energy Agency (2011). World Energy Outlook 2011. 9 November 2011. Paris
21. Japan International Cooperation Agency (2010). Country Paper: Energy Policy of Ethiopia. Presentation at Tokyo International Center, 10 May
22. Shanko, Melessaw (2009). Target Market Analysis: Ethiopia's Small Hydro Energy Market. Berlin. Available from www.giz.de/Themen/de/dokumente/gtz2009-entargetmarketanalysis- hydro-ethiopia.pdf.

Web Refernance

www.ruralelec.org

www.smallhydroworld.org

This page is intentionally left blank