DESIGN CONSIDERATIONS: SMALL HYDROPOWER GENERATION FOR RURAL ELECTRIFICATION

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Abstract
Small hydro power generation has been identified as a key contributor towards rural electrification in Kenya where 80% of the rural population is not connected to the national grid and there exists some potential for it mainly in the Mt. Kenya region and the Lake Victoria Basin. There are several small hydro plants that have been established in Kenya which are running but with various challenges due to the lack of proper feasibility studies being carried out to assess the site, poor demand estimation, poor design of the turbine and generator components, lack of trained manpower to carry out the periodic maintenance for proper functioning of the plant. The rural communities tend to be discouraged by the high capital cost which can be a result of over sizing of the equipments required and also if the maintenance is not properly carried out the running cost also become prohibitive and the projects are abandoned. This paper highlights the development on design of the small hydro plants made by JKUAT which resulted in fabrication of a pelton turbine wheel from re-cycled aluminium alloy. The pelton buckets attached to the wheel were anodized by an electrolytic process to harden the surface and reduce wear. The fabricated turbine has been able to generate 1Kw of power and provide technical and practical data for use in further design development.

Key words: Hydro-site selection, Renewable energy, Small hydropower, Turbine selection

1.0 Introduction
The use of hydropower can make a contribution to savings on exhaustible energy sources. Each 600 kWh of electricity generated with a hydro plant is equivalent to 1 barrel of oil (assuming an efficiency of 38 % for the conversion of oil into electricity).[Harvey, 1993] Fossil fuels are responsible for global warming because of the carbon dioxide that is produced with the use of coal power stations and other fossil fuel power stations. In order to stop a further decline in the environment and to replace non-renewable energy many different alternative power sources are being researched and implemented. One such renewable energy source is hydro energy. Hydropower is a very clean source of energy. It does not consume but only uses the water, after use it is available for other purposes. The conversion of the potential energy of water into mechanical energy is a technology with a high efficiency (in most cases double that of conventional thermal power stations).

1.1 Small Hydropower Basic Aspects
Small scale hydropower stations combine the advantages of hydropower with those of decentralized power generation, without the advance technical requirements of large scale installations. Small scale hydropower has hardly disadvantages: no costly distribution of energy, no huge environmental costs as compared to other sources of energy, independent from imported fuels and no need for expensive maintenance.

The context of small hydropower can be described as follows:

(i) Decentralized, small demand for power (small industries, farms, households and rural communities).
(ii) Distribution network with low voltages (eventually sub-regional grid).
(iii) Owned by a individual, co-operative or community with semi-skilled workers.
(iv) Short planning scope and construction periods with the use of local available materials and skills.
(v) Depending on generated power it can have a substantial impact on local standards of living (bigger than only the supplied power).
(vi) As only some information is available about the potential power often not more then 10 % of the potential is used [Barnett and Khennas, 2000].

1.2 Planning a Small Hydropower Sites

The definitive scheme comes as the result of iterative process, having in view the environmental impact, the different technological options, social and economic benefits. Although it is not easy to provide a detailed guide on how to evaluate a scheme, it is possible to describe the fundamental steps to be followed. There is a list of the studies that should be undertaken:

Topography and geomorphology of the site; this looks at the available Head, the gradient on which the penstock will be laid. Evaluation of the water resource and its generating potential i.e. the flow volume and rate. Site selection and basic layout; the appropriate location of the power house. Hydraulic turbines and generators and their control; this is the most essential and our interest lays here. Environmental impact assessment and mitigation measures; this is important in order to maintain the plant running at a constant power output. Economic evaluation of the project and financing potential; establishment of small enterprises as a result of this scheme is essential and his help raise funds for maintenance of the plant. Institutional framework and administrative procedures to attain the authorizations [Twidwell and Weir, 2001].

1.3 Design Preview on Already Installed Sites

A few field studies have been carried out on the functional status of the state of existing small-scale hydro plants in Mount Kenya region. Not only the much work on manuals, standards, training, and associated errors, but also the physical assets remain a substantial cause of failure. Corrective measures on the engineering aspect especially for the turbine- generator system need special attention. Some of the factors that have led already installed plants non–operational are:

(i) Poor site selection, inadequate/inaccurate surveys, wrong size, poor installation, faulty equipment.
(ii) Plants affected by floods and landslides.
(iii) Poor estimation of hydrology, in part due to surveys being conducted in the rainy season.
(iv) Uneconomic canal length (penstock), bad design.
(v) Neglect of civil works; lack of proper maintenance of the weir leading to siltation.
(vi) Inability of owners to replace generators and the turbine after breakdown.
(vii) Wrong estimation of raw materials, of demand, of end-use possibilities, oversized plants, over-estimation of tariff collection, inappropriate rates.
(viii) Steps by the government to extend Rural Electrification [Minas and Penche, 1998].

1.4 Impacts of Small Hydro Installations

There exists a great potential of reduction of greenhouse gases (GHG) in rural residential sector where fuel wood and fossil fuels still remain the major source of energy. The fuel wood in Kenya has not been utilized sustainably for a long time due to lack of good policies and this has led to destruction of the carbon sinks and increase of Carbon Dioxide (CO_2) at unprecedented rates into the atmosphere leading to the global warming phenomena that is characterized by extreme weather patterns e.g. severe droughts, Tsunamis etc. According to the Kenya Forestry Service (KFS) Kenya loses 54,000 hectares of forest cover every year due to harvesting of firewood, charcoal burning *inter alia* and therefore with small hydro power generation for rural electrification this is bound to change for the better. Communities that have benefitted from the SHP for example Nepal have reduced significantly the amount of firewood used for lighting, cooking and water heating which are the main uses of energy in the rural areas [Gurung 2011].

Use of power from SHP leads to reduction of Kerosene use for lighting and significantly reduces the firewood used in the rural household as per the study carried out in Nepal, therefore the cumulative effects of emissions reduction for the communities can earn carbon credits under the clean development mechanism which was set up under the United Nations Framework Convention on Climatic change to assist the Annex I countries which are the industrialized countries meet their targets of reducing the CO_2 emissions below the 1990 levels.

Most rural communities in Kenya that are not connected to the grid still use kerosene lamps, candles, charcoal and firewood for lighting, cooking and water heating. These energy sources apart from contributing to global warming they have detrimental effects on their health and are known to cause visual and respiratory diseases.

Education also benefits with rural electrification because the children are freed from the ineffective traditional lamps and the students can extend their study hours at homes and therefore they are motivated and enrollment is increased for both secondary and primary schools.

Local businesses are established e.g. welding, phone charging, lamp charging, car battery charging, computer training centre's and agro-processing activities e.g milling, egg Incubators, juice making and refrigeration etc. This has worked well for the communities that have already established energy kiosks through UNIDO in Kenya [UNIDO, 2010].

1.5 Distribution of Small Hydro Potential in Kenya

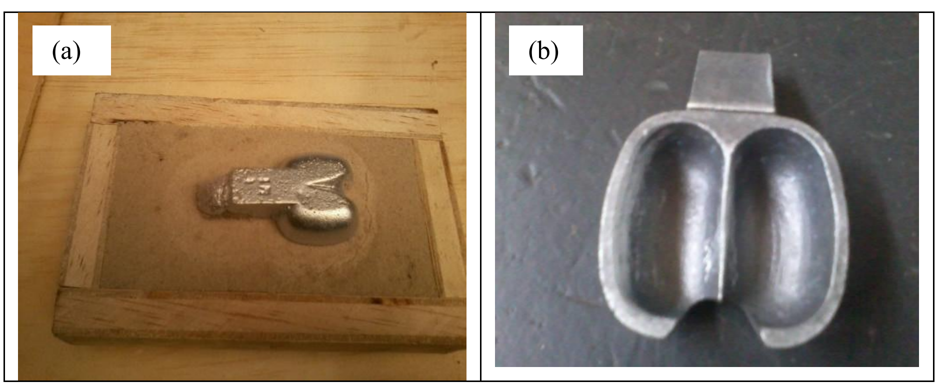
The potential small hydro sites are located in the south-west of Kenya the lake Victoria Drainage Basin in Nyanza and western provinces and adjacent districts of Rift Valley as well as in areas south-West of the line of Mount Kenya-Aberdare mountains (Central Province, Mt. Kenya adjoining districts of Eastern Province and Laikipia District of Rift Valley Province). Thus the SHP potential is concentrated in districts, which have also high population density and high energy demand.

1.6 Turbine Design Considerations

1.6.1 Pelton Turbine

The Pelton turbine was designed to produce 1kW of power and was sand casted from used aluminum alloy wheels. The buckets were also made of aluminum but were casted in sodium silicate bonded sand molds. After casting they were cleaned to remove grease and surface dirt before being attached positive terminal of a DC power source so that they formed the anode. The cathode was made of copper plates that lined the electric cell. The electrolyte was prepared to 10% from concentrated sulphuric acid. A power supply set at across the terminals to provide a voltaic potential difference of 12 volts. The Figure1 (a) shows the cooling casting section in the carbon bonded sand. Figure 1(b) shows the anodized pelton bucket.

The turbine consisted of a set of specially shaped buckets mounted on a periphery of a circular disc. It was designed such that jets of water discharged from one or more nozzles would strike the bucket and pelton wheel that was coupled to a turbine. Buckets were split into two halves so that the central area water deflected away from the oncoming jet. Figure 1(c) shows the picture of the actual pelton wheel assembly while Figure 1 (d) shows an explode view of the turbine design.



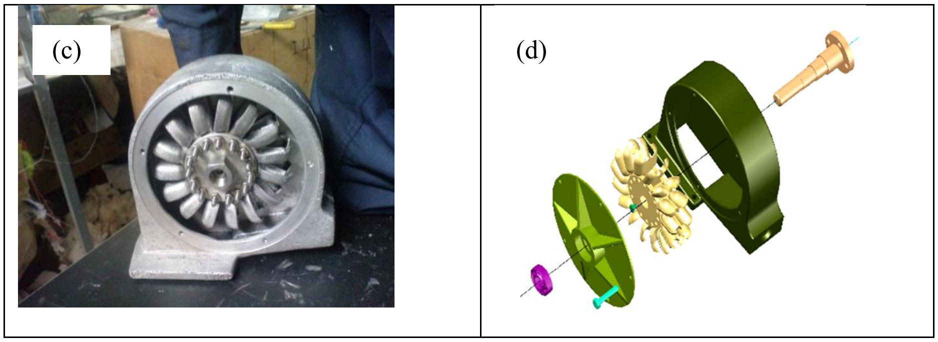


Figure 1. A Pelton turbine fabricated at JKUAT

1.6.2 Pelton Turbine Test Bench

A test bench was fabricated by JKUAT Mechanical Engineering workshops whereby a pump was used to simulate the head and an induction motor connected in reverse was used to generate electric power. A distribution board with a number of light bulbs was used to simulate the household load. The design was compact and could be used to simulate the actual site conditions. Other types of turbine can be tested on the same bench.

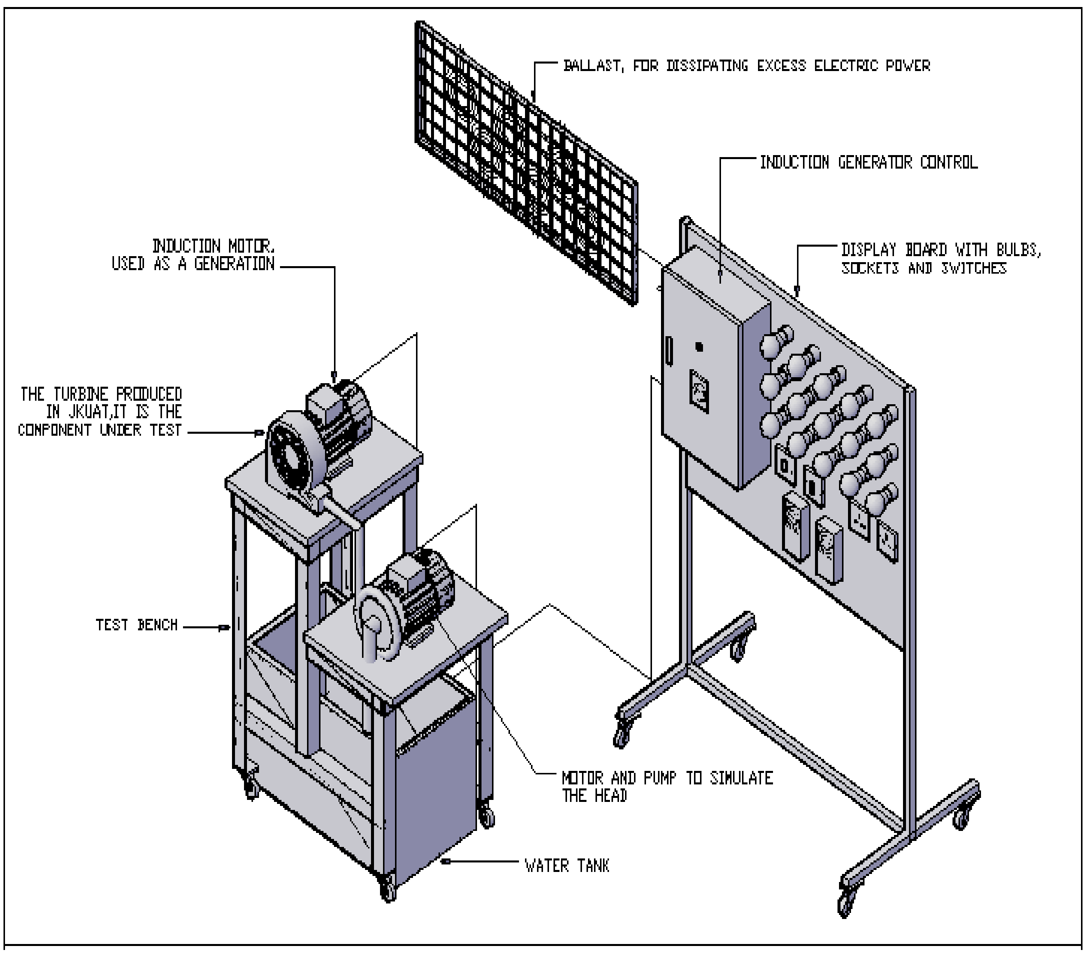


Figure 6a: The test bench at JKUAT

2.0 Conclusion

The hydro turbine was able to produce 1 kW of power and capable to light bulbs with an equivalent number of bulbs.The pelton turbine can be used in rural areas to replace traditional energy sources.

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