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Design Detail of Microhydro System and Findings Based on off-Grid Project

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ABSTRACT

The purpose of this research paper is to conduct a literature review regarding the technical specifications and design parameters required to design a functioning Micro Hydro Power System MHS (Micro Hydropower System). After review of the theory and principles of Micro Hydro System design; these principles are applied to the real case of Bhoot Khola Micro Hydro Project in Deurali Village Development Committee (VDC) of Tanahun Nepal. The field data required to design the civil components of the micro hydro project were derived from secondary data sources such as the study conducted by the village development committee as well as other independent project surveys. The micro hydro designed in this thesis was of "run-of-the river" type. Similarly, system components designed in this thesis are intake structure, headrace canal to divert the water from the source, forebay tank, sedimentation basin and the penstock assembly.

Keywords: *Micro Hydro, Bhoot Khola, Nepal, Micro Hydropower System, Tanahun*.

1. INTRODUCTION

In a hydropower system, the energy present in water is converted into mechanical or electrical energy in hydropower plant. Generic hydro power systems can be categorized in different ways. Some of the methods of classification are based on how the electricity is generated by the plant, what kind of grid system is utilized for the distribution of electricity, the type of load capacity and the type of storage used by the system. (Pandey, 2006)

1.1 Power Generation Capacity

Although various categorizations exist based on different locality and nationality, the generally accepted classification of hydro power plants based on the ability to generate power is provided in Table 1.

Table 1: Common Classification of Hydro Power Plants (HPP) based on Capacity Generation (Bhattarai, 2005)

Power Generation Capacity (Watts)	Type of Hydro Power Plant
<100 Kw	Micro
100-1000 Kw	Mini
1MW-10 MW	Small
10MW-300 MW	Medium
>300 MW	Large

Generally, hydropower plants (HPP) generating less than 100kW of electricity are termed as micro HPP; those generating 100 to 1000 kW are termed as mini HPP; those anywhere between 1 MW to 10 MW are termed as small HPP; between 10 MW to 300 MW are termed as medium HPP and those with the power generating greater than 300 MW are termed as large HPP. Although variations in definitions exist; this is the most commonly accepted definition (Bhattarai, 2005).

1.2 Types of Storage

Based on the type of storage used in hydro power plants they can be classified into "storage type" or "run-of-the- river" type. The major difference between these types of hydro power plants is that in the former, a dam is constructed to act as reservoir of water sources and has ability to continuously supply the water in undulating manner. However, in the latter, "run-of-the river" type, it is constructed by directing the water source to the turbine and the water source may vary according to seasons. "Storage type" are used generally in small to large hydropower plants whereas "run-of-the river" type are more common in micro, mini and small hydro power plants (Bhattarai, 2005). In this study, “run-of-the-river type” of micro hydro plant is designed at a later stage.

1.3 Types of Grid System

Based on the type of grid system, hydro power plants can be classified into local grid and extensive grid systems (Hydraulic Energy Program et al., 2004). In the local grid system, the electricity is generated and distributed only for the small locality, without use of any sophisticated electromechanical distribution systems. In contrast, in an ex-tensive grid system, the electricity generated by the HPP (Hydro Power Plant) is loaded in a form of extensive grid such as the national grid system. Generally larger HPP (Hydro Power Plant) are of these types but in this study, focus is paid to the local grid sys-tem. Similarly, based on the load of the distribution system HPP (Hydro Power Plant) have been classified into base load plant and peak load plant but it is beyond the scope of this study; as the system designed in this thesis does not consider these factors.

2. GENERAL PRINCIPLE OF MICROHYDRO SYSTEM (MHS)

Micro hydro power plants are designed to generate electrical or mechanical power based on the demand for energy of the surrounding locality. In a typical MHS (Micro Hydro-power System) the water from the source is diverted by weir through an opening intake into a canal (Fox, 2004). A settling basin might sometimes be used to sediment the foreign particles from the water. The canal is designed along the contours of the landscape available to preserve the elevation of the diverted water. The water then enters the fore-bay tank and passes through the penstock pipes which are connected at a lower elevation level to the turbine. The turning shaft of the turbine is then used to operate and generate electricity (Simoes, 2004). The machinery or appliances which are energized by the hydro scheme are called the load. A typical MHS (Micro Hydropower System) layout is provided in Figure 1.

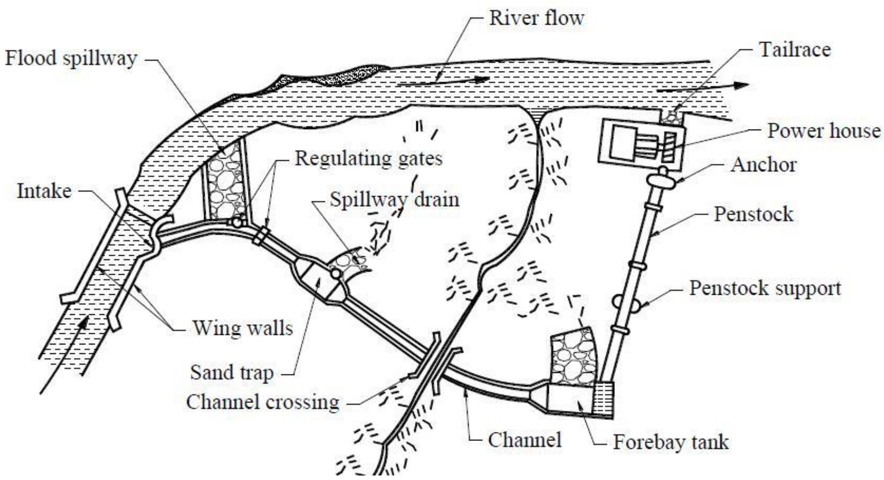

Figure 1: A Typical MHS (Micro Hydropower System) Configuration (Pandey B., 2006)

2.1 Discussion Micro Hydro Systems

The focus of this study is to design a Micro Hydro Power System (MHS) at a later stage. Therefore, after classifying the generic hydro power systems in section 1.1, this section will be focused on describing different types of MHS (Micro Hydropower System). The factors that affect the choice of MHS (Micro Hydropower System) are the needed capacity from the project, the anticipated demand for power from the locality and the profile of the project. The major factor that needs to be assessed before-hand are whether the MHS (Micro Hydropower System) will be connected to some grid system for delivering electricity or just be a standalone system which is not connected to any electrical grid system. When the MHS (Micro Hydropower System) is planned to be at a remote site, it could either be battery based or AC direct system. However, if it is to be connected to the electrical grid then AC direct systems are more appropriate. (Hydraulic Energy Program et al., 2004) The final choice will ultimately be influenced by many other factors which are going to be explained in the following section.

2.1.1 AC direct Systems

This type of MHS (Micro Hydropower System) is designed to supply the load directly, as it does not use battery as storage. This is the most common system that can be found in normal use and is most suitable for grid connected sites and remote standalone sites. The smallest available fully integrated system of this kind is 200W which can work with the head (this concept will also be explained later) as low as 1 meter (Hydraulic Energy Program et al., 2004). When the larger unites are required due to capacity or site profile, they are manufactured and assembled accordingly.

2.1.2 Grid Connected

When there is already a grid supply available it is possible to still install a system and obtain electrical power from both the MHS (Micro Hydropower System) and the grid supply. It is possible to supply the excess power generated from MHS (Micro Hydro-power System) to the grid through "net metering" (Greacen, 2004). A single meter measures the electricity purchased from the utility and turns backward when the small power producer feeds electricity into the grid. The net-meter measurement determines the amount of electricity charged to the user. Net-metering programs are in various stages of development in British Columbia, Alberta, Manitoba and Ontario. Each utility has its own policy for grid connections.

2.1.3 Hybrid Systems

Hybrid system is a system where different sources of power are used to generate electricity. It could include any combinations of wind, photovoltaic system and MHS (Micro Hydropower System) There are several advantages of hybrid systems over single type of system, because it is possible to offset the low peak period of one source by high peak period of the alternate source. For example, when wind and photovoltaic sources are installed together, wind speeds might be low in summer but then sun shines bright-Project), which is a perennial source of water with sufficient discharge also in the dry season.

3. MEASURING POTENTIAL POWER AND ENERGY

According to the Bernoulli energy equation, (Fox, 2004) energy in water is stored in terms of pressure energy, velocity energy and elevation energy. It can be further stated as:

Power (Energy/sec) = Pressure energy/sec + velocity energy/ sec + elevation energy/sec or,

p 2
P Z
— G —
— + v 2g +
ρ

Where,

P = electrical or mechanical power produced, W
ρ = density of water, kg/m^3
g = acceleration due to gravity, m/s^2
z = elevation of the point above the reference point v = velocity energy of the water

The potential power that can be generated from the micro hydro power plant is often calculated from the survey of the site (Pandey B. , 2006).The difference in the energy is converted into useable energy by the hydropower plant when there is a difference be-tween energy of the water. Therefore,

p 2
P Z
— G —
— + v 2g +
ρ

Or,

$$P= (p/\rho g+v^2/2g+z)_{intake} - (p/\rho g + v^2/2g+z)_{exit}$$

However, there will be some loss of power while the available water energy is convert-ed by the hydropower plant. The actual power that can be generated from the given source of water is thus,

$$P=\rho.g.H.Q.\eta \quad (1.1)$$

Where,
P = electrical or mechanical power produced, W
ρ = density of water, kg/m^3
g = acceleration due to gravity, m/s^2
H = elevation head of water, m
Q = flow rate of water, m^3/s
η = overall efficiency of MHs (Micro Hydropower system

It can be seen clearly from the equation that the power generated by the water available depends upon the flow rate of the water, elevation head (elevation difference between intake and exit of water), and gravitation force, density of water and efficiency of the hydropower system. The goal of the hydro power is to convert the available water energy into mechanical or electrical energy.

4. DESCRIPTION OF THE CASE

Deurali VDC lies in the western part of Nepal, in the mountainous regions where the elevation of the proposed site for the MHP (Micro Hydro Project) is above 1000 mean sea level. Before discussing the design of primary components of the MHP (Micro Hydro Project), it is necessary first to discuss the preliminary data available through the feasibility survey. The survey team appointed by Deurali Village Development Committee made detailed engineering survey at around summer of 2010. Detailed measurements were carried out to locate the best position for intake, headrace canal, forebay, power-house, tailrace and the spillway. Some of the important parameters that were measured were published by Deurali VDC and have been used in this study as secondary source of data. Some of those important survey parameters are discussed in this section.

The report published by Deurali V.D.C. on Bhoot Khola River shows that the flow of water measured on 12th of May, 2010 was 0.204 m^3/s. However, as the report ex-plains, design discharge was taken to be 0.154 m^3/s, after considering that 15% of the calculated lowest flow downstream releases due to environmental reasons and 10% of the discharge were lost through evaporation or seepage. The survey team used floating ball method to calculate the water flow and to derive the design discharge from this data. The detailed results of the mean monthly flow of Bhoot Khola River, is shown in Table 2.

Table 2: Mean Monthly Flow of Bhoot Khola River (Deurali Village Development Committee, 2010)

Month	Flow at River, Liter/ Second
January	535.44
February	402.69
March	300.91
April	221.26
May	201.34
June	604.34
July	2480.30
August	3084.34
September	2212.58
October	1442.60
November	1006.72
December	736.79
Annual Average	1102.42

Deurali VDC also conducted the survey about the energy consumption pattern in Deurali VDC and the estimated demand for electricity, to determine the power out-put of the MHP (Micro Hydro Project), which would be able to satisfy this demand.

5. CONCLUSIONS

Although, this research was about designing the system components for a MHP (Micro Hydro Project), majority of the system components discussed included only limited topics. However, the research would have gone beyond its limitation in scope and length if the design parameters and design process for other civil components such as the physical powerhouse have been added.

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