ECONOMIC FEASIBILITY STUDY OF GRAVITATIONAL WATER VORTEX POWER PLANT FOR THE RURAL ELECTRIFICATION OF LOW HEAD REGION OF NEPAL AND ITS COMPARATIVE STUDY WITH OTHER LOW HEAD POWER PLANT

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ABSTRACT

The research work on GWVPP till now have found that the different geometrical parameters like (i) basin opening, (ii) basin diameter, (iii) notch length, iv) canal height, and v) cone angle are predominant in the design of basin structure of the Gravitational Water Vortex Power Plant and also shown that the conical basin structure is more efficient than cylindrical basin structure. The study shows that the conical basin structure have 75% efficiency which is about twice more efficiency than the cylindrical basin structure. The past experimental study on three profiles of runners for GWVPP also shows that the runner having curved profile is more efficient than straight profile. Hence the gravitational water vortex power plant is now in the final stage of commercialization in Nepal. So this study encompass the economic feasibility study of the optimized conical basin and runner for the GWVPP in context of Nepal and the economic aspect of conical basin structure is compared with the economic aspect of various other type of low head power plant used for the power production. Also the comparative study of the economics aspect of GWVPP with the economic aspect of existing large hydropower projects of Nepal.

KEYWORDS

Gravitational Water Vortex Power Plant, Conical Basin, Geometrical Parameters Mathematical, Model, Optimization

INTRODUCTION

The world is competing for energy and hydropower is a clean source of energy or electricity. The field of Hydropower has often witnessed the discovery of new types of plants and components therein, by using simple principles of physics and mechanics. Gravitational water vortex power plant (GWVPP) has lately been eye-catching and interesting topic for researchers throughout the globe.

Gravitational Water Vortex Power Plant is a new technology in which potential energy of water is converted to kinetic energy by a rotation tank (basin) and this kinetic energy of water is extracted by a turbine in the center of vortex.

Gravitation water vortex power plants do not need a large head like other hydroelectric plants; they can operate on heads as low as 0.7m. The construction costs are relatively small. This makes them suitable on rivers across the Nepal, at thousands of locations. This has the possibility of removing the need for mega hydropower stations. The installation of GWVPP can act as an exemplar project that can have huge benefit with no negative environmental impact. Moreover, GWVPP is safe for fish due to low turbine speed and improves water quality by oxygenation. Thus, for a developing country, like Nepal, this technology of power production is a boon to eradicate energy crisis.

OBJECTIVES OF THE STUDY

The objective of this paper is:

i) To conduct the case studies of the economic aspect of various low head turbine technology used in Nepal and compared it with GWVPP.

ii) To compare the economic aspect of the GWVPP with the economic aspect of existing large hydro power projects of Nepal.

Findings from this study will be considered as vital input in study of economic aspects of comer-cialization of Gravitational Water Vortex Power Plant for the rural electrification of rural communities of Nepal.

GWVPP IN NEPAL

Although the research on the GWVPP is started in the world in the year 2007. The Research on the GWVPP started in the year 2012 in Nepal in Tribhuvan University, Central Campus Pulchowk, Institute of Engineering. In first year the main area of focus was to develop innovative low head water turbine for free flowing streams suitable for micro-hydropower in Terai region of Nepal. In the study, water vortex was created by flowing water through an open channel to a cylindrical structure having a bottom whole outlet. The research concluded that basin geometry depends on the discharge supplied.

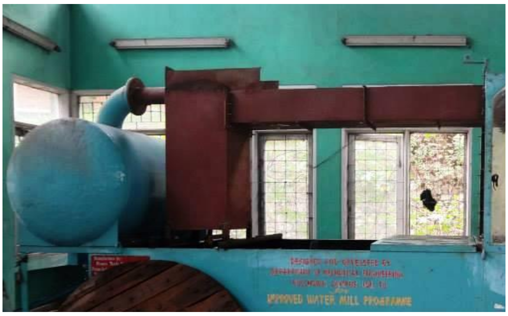

Figure 1. Test Rig for the experimental study of GWVPP in IOE in year 2012.

Figure2. Runner for the power production.

In the year 2013 the study was carried out in two phases. In the first phase, two different turbines were designed and fabricated and the performance characteristics of the new turbines were compared with that of the Old turbine. The second phase included the design and fabrication of the conical basin. Experimental tests were carried out and the performance of the system using the conical basin was compared with that of the system using the cylindrical basin. The value of velocity head increases with the increase in depth. Hence greater efficiency was noted at the bottom most position. Similarly, the values of efficiency were greater for turbines with smaller number of blades. There was a significant distortion of vortex even with smaller loads in case of the turbine configuration with greater number of blades. Also, increase in the radius of the blades caused a decrease in the efficiency of turbines. The tests also indicated that the vortex strength of water in the conical basin is greater than that in the cylindrical basin. Consequently, turbine efficiency was greater in the conical basin compared to the cylindrical basin.

Figure 3. Cylindrical Basin Structure.

Figure 4. Conical Basin Structure.

Figure 5. Test Rig for the experimental study of conical basin structure.

In the final year of the research and analysis of various geometrical parameters of conical basin design of the vortex plant was done. For given flow and head, the following parameters were considered: (i) basin opening, (ii) basin diameter, (iii) notch length, iv) canal height, and v) cone angle. The parametric effects on vortex formation and energy are evaluated in terms of vortex velocity by using state of the art procedures of Computational Fluid Dynamics (CFD). Different basin configurations were developed by using Solid Works software and the models were simulated in the CFD code of ANSYS Fluent. Each parameter is varied individually and corresponding velocity (within a range of interest) is noted, which is followed by a development of mathematical model and is optimized using EXCEL. The so developed optimized model is fabricated and tested.

Figure 6. Various Profile of runner used for the power production.

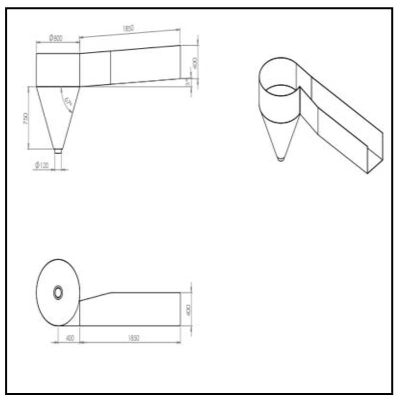

Figure 7. Optimized design of conical basin structure.

Now the GWVPP is in the final stage of commercialization in Nepal but the study of runner is yet to be made. The primary economic analysis shows that the cost of production of 1kw system is around 3 lakhs. This may vary according to cannel length, cost of civil structure to be made.

COMPARITIVE STUDY WITH OTHER LOW HEAD POWER PLANT (CASE OF IMPROVED WATER MILLS AND PICO HYDRO)

Improved Water Mills

The Improved Water Mill (IWM) is a modified version of traditional water mill. IWM is an intermediate technology that increases the efficiency of the traditional water mill resulting in increased energy output thus helping both the millers and its users. The improvement covers basically the replacement of wooden parts (rotor, shaft and chute) with metallic parts. This increases its operational efficiency as well as making it more useful with additional machines for hulling, electricity generation and so on. The rotations per minute (rpm) of the shaft range around 200-300 rpm while the power output ranges from 0.5 kW to 3 kW. The grinding capacity ranges from 20- 50 kg maize per hour. The frequency of repair/maintenance of IWM is low in comparison to TWMs while the life span is around 10 years. The chute I s mostly wooden, sometimes however are found also of polyethylene or of tin sheet.

IWM technology can generate up to 3 kW of electricity sufficient for lighting and operating small electric and electronic devices such as television, radio, computer, battery charging stations, and other small electric home appliances.

Figure 7. Improved Water Mills

Improved Water Mill in Nepal

The history of development of Improved Water Mill (IWM) in Nepal dates back to the early 1980s, when the Research Centre for Applied Science and Technology (RECAST), a research and development wing of Tribhuvan University (TU), developed a prototype of an improved version of water mill. In the prototype wooden paddles were replaced by hydraulically more efficient metallic blades, and a new bottom bearing. This prototype with a closed chute and a covered chamber was tested in a mill at Godavari, Lalitpur.

The technology was subsequently promoted among the farmers with involvement of a manufacturing company, the Kathmandu Metal Industries (KMI). The unit was called Multi- Purpose Power Unit (MPPU). A number of farmers adopted the technology; the experience of this effort was critical in further improving the technology and gain experience on its social acceptance.

Major efforts towards the improvement of water mill were initiated by GTZ/GATE under "Activating Traditional Indigenous Techniques" program in which the traditional water mills were improved by using local materials and skills of village craftsmen. While the metal parts mainly the kit runner, shaft/axle, and belt/pulley were improved the other parts of the water mill such as chute, framework, stone grinder, canal and intake were kept intact without any change. This provided the interested entrepreneurs an opportunity to install IWM with low investment. For generation of 1kw power the cost of installation is about NPR 3,8000W. Operational cost varies according to the type of end use.

Economic Aspect

Before the installation of IWM electrification, most of the villagers were using kerosene for lighting. Around 1.5 liters of kerosene was consumed per household per month. At NPR 70 per liter, the 35 households of the community spent about NPR 44,100(USD 555.2) on kerosene annually. This expenditure was reduced to NPR 21,000 after the community installed an IWM of 3kW for electrification. IWM program also promote the women empowerment as the time and effort given to the hulling of maize and other crops gets lower.

Pico Hydro

The development of Pico Hydro Power plant is started by the organization PEEDA in Nepal. Pico Hydro system are used in remote areas to supply electrical power to areas with no grid connection. They are usually intended for lighting application. Micro Hydro Power plant are of size 200W to 2KW. To address the commercialized utilizetion of Pico Hydro Power plant PEEDA recently has developed a new controller in the industrial collaboration with Kathmandu Energy and power Group (KAPEG) under Renewable Nepal Program. With the new excitation system and control system added, new ELC is able to start the drill machine, television, computer and other electronic equipment's that require high inrush current to operate. Thus for the first time, Pico hydro system with self-excited induction generator can be used to operate income generating power tools and processing equipment's. Despite the initial cost per KW, the minimal cost required for running the scheme and great potential for it to open up new revenue streams, make the technology not only economically feasible, but also profitable for the poor communities of Nepal. The electrification of people's homes reduce their use of fossil fuel and traditional biomass.

Comparison of economic aspect with other low head power plant

In comparison to economic aspect of other different low head power plant like IWM, Micro Francis, Pico Propeller, cross flow turbine etc. The cost of installation of the Gravitational water vortex power plant is comparable to all of us. The major benefit of the installation of GWVPP is GVP plants can use local materials and do not need to dam the water to operate. The GVP plant merely uses the water for a few seconds as it flows on its way down stream. GVP is designed to be installed in remote areas of flat region that would never see grid expansion into local villages and is designed to electrify a small community of up to 200 homes per plant under Nepali consumption pattern. As most cottage industries are located in such sector they can be benefited. Hence Gravitational Water vortex Power Plant can be a step toward a green industrial development as the materials used for construction of GVPP be bought locally and those living close to the GVP plants can maintain and repair the generators and mechanical components themselves. Thus GVPP installed in existing irrigation projects is economic way of Agro based industrial Development and also for rural electrification electrical poles. This means revenue circulates throughout a local area and the community sees a direct economic benefit. Thus GVPP installed in existing irrigation projects is economic way of Agro based industrial Development and also for rural electrification.

Comparison of economic aspect with large hydro power plant

We have taken a large-scale project first, the Upper Tamakoshi Hydroelectric Project. The project cost is estimated at NRs.35.29 billion equivalent to US $441 million excluding interest for five years on the project (with exchange rate of 1US$= NRs. 80) and will have a Maximum Output of 456MW per day during the monsoon. Cutting that number by 60% or more during the dry season. The additional cost is in 132 kV High Voltage Transmission Lines for future grid extension between$8000–10,000 per km and rising to around $22,000 in difficult terrain. Sub-station construction and additional road building at $20,000per km. Hence the project cost would be round off to $500 million and also these lines will bypass most rural communities on its way to India in Power Purchase Agreements (PPAs).

Comparing smaller GWVPP plants using local materials, the cost of each plant can comes in around$10,000 and does not dam the water in order to operate. The GWVPP plant merely uses the water for a few seconds as it flows out the bottom on its way downstream. Just the environmental advantages to its usage warrant further investigation as a solution.GVP is designed to be installed in remote areas that would never see grid expansion into local villages and is designed to electrify a small community of up to 200 homes per plant under Nepalese consumption patterns.

If we use the same figure of$500 million for one large project that provides diminishing electrical output as rains decrease from October to May each year, we could build 50,000GVP plants. These plants generating 57 MWh per year would equal 2,850,000 MWh or 2,850 GWh annually fed directly to the local communities in remote locations that need it most. The forecast annual energy output from the „Upper Tamakoshi Hydroelectric Project' is 2,281GWh. We can generate more power from GWVPP, save on the amount of construction materials and do not need to dam an entire river.

CONCLUSION

The feasibility study showed that low head Gravitational Water Vortex Power Plant fill a gap in the Nepalese renewable Energy Market. This study shows that GWVPP is viable and attractive option for poor rural communities and can greatly benefit them. Around 50000 such sites are highly suitable for the low head Gravitational Water Vortex Power Plant. Wide range of benefits includes socio-economic, financial and environmental gains. The low head GWVPP also provides an opportunity to address current rural/urban and regional energy access disparities of Nepal.

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