Analysis on Rainwater Harvesting and its Utilization for Pico Hydro Power Generation

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***Abstract*— India being a developing country is constantly in search of an alternative source of energy towards generating electricity. One of Green Energy technology is the Hydro Power technology, which can be targeted to reach the power demand for utilization of natural renewable sources of energy such as rainwater, sunlight, air etc and sustainable water management through rainwater harvesting system. In hydro power technology the rainwater is the renewable source, which is used for the generation of the power for the economic source of maximum power generation of 5KW. Some of the devices that can be harnessed utilizing Pico hydro power are light bulbs, radios, television, refrigerators and food processors. For domestic power generation through roof top rainwater harvesting rainfall data of different places in India is collected and a relationship establishing potentioavailability is investigated the flow of water from the roof of tank with small water flow with enough head are met. The objective for its economical use and its management using a pelton wheel is studied because of its low flow for a planned community where electricity is produced by spinning of the turbine installed in the basement of the multi storey building capable of producing power less than or upto 5KW with virtually no negative environmental impact. Pico hydro power generation is an ideal solution of generating power that can turn out to be a blessing of modern technology for resolving the energy needs for the people, whom lack of electricity, is one of the main cause. It is an eco-friendly clean power generation method.**

***Index Terms*— Pico hydro power (PHP), Pelton Turbine, Rain Water.**

I. Introduction

The major source of electricity in India is the Hydro Electric Power. Hydro Technologies are associated with zero air emissions with electricity production are considered to be 'Green Energy' among solar, wind, geothermal and tidal energy, Hydro Power contributes 83% of the renewable energy source (RES) [1]. Support of each country for the use of RES for electricity based on the Kyoto Protocol and Bali Climate Change Conference should be encouraged [2]. Small hydro power systems (SHPS) in many cases are suitable for a group of users or individual users independent of the electricity supply grid. On a commercial scale SHPS are classified by power and size of waterfall serving a small community for the application of hydro power. Pico hydro powers (PHP) due to their environment friendliness have become a topic of growing interest. PHP can be designed to limit the intrusion with flow of river or canal as it an eco-friendly renewable energy resource (RES) [3].The activation and utilization of the potential energy that is inherent in the drinking water stored in high-level tanks of RWH system installed in a multi storey building is of growing interest. The maximum electrical output power of 5 KW comes under Pico hydropower [4].

Concept of Rainwater Harvesting

Water harvesting can be defined as the "collection of runoff for its productive use". Overflow or Runoff may be harvested from roofs and ground surfaces. Water harvesting techniques which harvest the runoff from roofs or ground surfaces fall under the term**:** Rainwater Harvesting.

The concept of RWH in a designed community providing wireless electricity free from problems related to uprooted trees and dislodged wires during typhoon is both easy, prehistoric and systems can vary from small and primary to large and complex. For the interval of dry seasons or non rainy days, vacuumed pumped from accumulated rainwater in tanks on ground level can produce electricity even during high peak demands, but during tropical storms electricity will be geographically produced from raindrops and gravity for an energy basis provided by Mother Nature, every rainy day continuously [5,6,7,8]. Rainwater harvesting (RWH) mainly consists of the collection, storage and consecutive use of captured rainwater as a supplementary basis of water. Both potable and non-potable applications are viable. Systems that provide water for domestic, commercial, agricultural, livestock, groundwater recharge, flood control, process water and as an emergency supply for fire fighting and institutional and industrial purposes are some of its examples.

Fig 1.1 Rain Water Collection in Multi-Storied Building

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Pelton Turbine

It is a tangential flow impulse turbine named after L.A.Pelton, an American Engineer. In Pelton turbine or Pelton wheel the water strikes the bucket along the tangent of the runner water is piped down through the PVC pipe so that at the lower end of the pipe water strikes the blades at a higher velocity. At the inlet of the turbine the energy available is the Kinetic Energy and at the inlet and outlet of the turbine the pressure is the atmospheric pressure as shown in figure 3.3. In small scale hydro power systems pelton turbine can be used [9] particularly in Pico hydro systems due to its sustainability [10]. Pelton turbines are used both in potable and non-potable applications with low amount of water and medium pressure having half the speed of jet of water equal to its constant circumferential speed [11].

$$C_v = \sqrt{2gH}$$

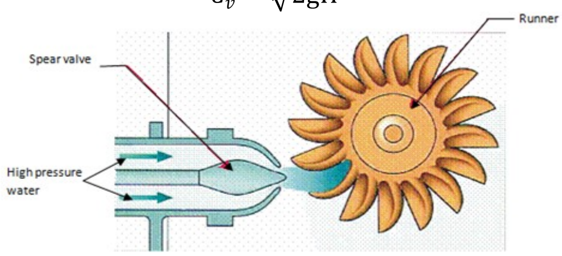

Fig 1.2 Pelton Wheel

II. METHODOLOGY

1. To study the operation work of Pico-Hydro Home System.
2. To identify the most suitable turbine type of Pico-Hydro Home System.
3. To calculate the output energy generation monthly with the help of rainfall data.
4. Estimate how to make the generated power can be suited in the different states of India.

2.1 Operation Work

The multi storey building, depends on the square area of the rooftops and gravitational flow of the rainwater by simply storing water in the high level tank, will be classified as small to mini or micro hydro in capacity of providing the energy. The important elements of a Pico-hydro plant, as shown in fig.2.1, are: water tank and vane; supply pipe; hydro turbine; DC generator and controller. Many times, the Pico-hydro plants are used together with other power plants, like wind turbine or solar photovoltaic panels.

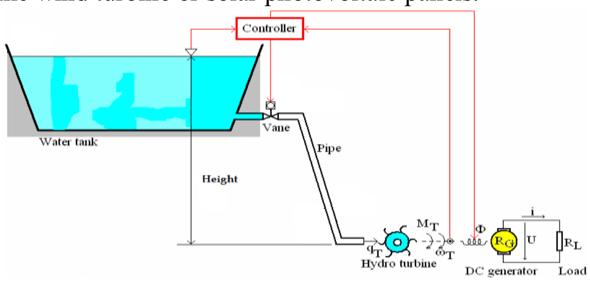

Fig 2.1 Pico Hydro Home system

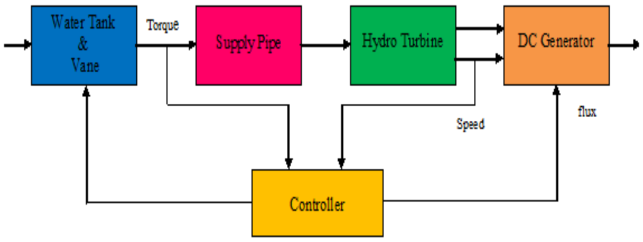

Fig 2.2 Pico Hydro System Block diagram

2.2 Flow chart for the Capacity Calculation of Pico Hydro

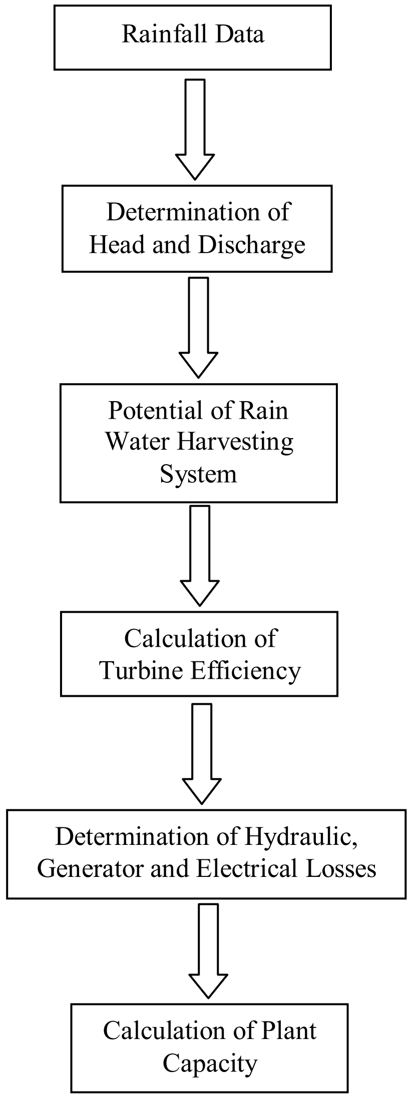

Fig 2.3 Flow Chart for the capacity calculation of Pico Hydro RWH system

2.2.1 Discharge, Potential and Power Assessment

The amount of energy that will be produced will be reliant on two things:

1. The Flow of the Water OR Discharge: The flow of water is simply the quantity of water flowing in the water source.
2. The Head: Head refers to the pressure at which the water hits the turbine blades, and is the vertical distance from the water source to the generator. In article 3.3.5 of Code for Design of Building of water supply and Drainage vertical

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division should be incorporated for domestic water supply system of high rise building. The larger the distance that the water falls before it hits the blade, the higher the head.

2.2.2 Rainwater Harvesting Potential (Supply)

In order to generate useful amounts of power for a multi storey building ,both from the available head and the flow-rate, it is necessary in determining power using volumes of water captured through Rain Water Harvesting System having the following basic equations like:

$$P_{max} = \rho \times Q \times g \times H$$

Where, P max = power

Q = volumetric flow-rate

H = gross head

ρ = density of water

g = gravitational constant

RWH Potential (m^3) = Rainfall (m) X Catchment Area (m^2) X Collection Efficiency

The power equation is modified by an efficiency factor (η):

$$P = Q \times H \times g \times \rho \times (\eta)\, effective$$

This equation gives a practical approximation of the power output of a hydroelectric system despite of its construction or size.

Low Head is the lagging factor for the utilization of generating electricity and it is a defeating factor in the Power equation when relying on rooftop rainwater collection system. The main strategies basically that can be found from the literature survey to cope with the head variation effect can be summarized as follows:

1. For a multistory building considering a constant average net head obviously [12].
2. Iterative procedure will be carried out where each iteration considers a fixed head, updated in succession.
3. Equating the values by making a realistic approach in the Mat-lab simulation through programming and cross checking the availability and sustainability of Pico Hydro Power Generation through RWH throughout Indian States for its sustainability of power generation to find a solution.

2.3 Estimation of Turbine Efficiency

2.3.1 Steps needed to determine the Pelton turbine Efficiency [13]

1. Velocity Of jet $(V1) = Cv\sqrt{2gH}$
2. Discharge through jet = Area of jet × V_1

$$Q_2 = \frac{\pi}{4} \times d^2 \times V_1$$

3. For a Pelton Wheel Turbine the no of jets can be from 2………12
4. Jet Ratio (m) $= \frac{D}{d}$
5. No of Buckets on the Runner (Z) $= 15 + \frac{D}{2d}$
   (Z) $= 15 + 0.5x\, j$
6. Velocity of wheel (u) = $\varphi\sqrt{2gH}$
7. Diameter of Runner $(D) = \frac{49.4 \times H^{0.05} \times j^{0.02}}{N}$
8. From velocity triangle at inlet Runner velocity
   Vr1=V1-u
9. From velocity triangle at outlet jet velocity
   Vw1=Vr1+10, φ=180º-160º
   Vw2=Vr1×Cos 20º – u

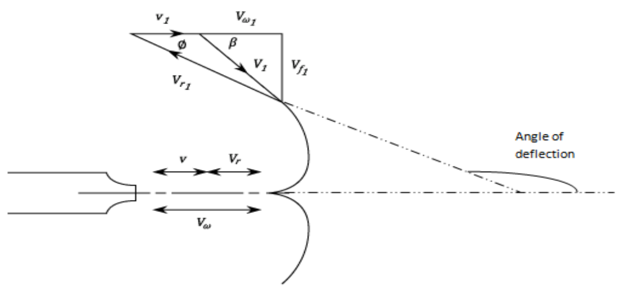

Fig 2.3- Velocity Triangle

10. W.D by Jet on the Runner=$\rho \times Q \times V1(Vw1 + Vw2) \times u$
11. HP given to the Runner=$\frac{\rho \times Q}{g}\left(\frac{Vw1+Vw2}{75}\right)\times u$
11. SHP=$\frac{\rho \times QV1}{2}$
12. WHP=$\frac{\rho \times Q \times h}{75}$
13. Hydraulic Efficiency $(\eta h) = \frac{HP}{WHP}$
14. Mechanical Efficiency $(\eta m) = \frac{SHP}{HP}$
15. Overall Efficiency (ηo) = (ηh) × (ηm)

2.3.1.1 Design of Pelton wheel [15]

1. Diameter of the jet (d)
2. Diameter of the wheel (D)
3. Width of the buckets which is=5× d
4. Depth of the buckets= 1.2×d
5. No of buckets on the wheel.

3.5 Generated Power Estimation/Plant Capacity

According to the principle of conservation of energy "power can neither be created nor destroyed" so in this process some power is lost and some power produced by the hydro power system is converted from one form to another [14]

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Without affecting the quality and quantity of output as shown in the figure .**G**enerators and turbines together have the efficiencies of over 90%. For the proposed system of Pico Hydro RWH system where the output power is limited by the power loss in the pipeline (mechanical power by hitting the turbine blades i.e. 30% of the total hydro power is lost going out from the pipeline to the turbine) and the size of the inverter and turbine both [15,16].

$$P = Q \times H \times \rho \times g\,(1 - lhydr)\,\eta \times eg\,(1 - ltrans)\,(1 - lelect)$$

Where, η = turbine hydraulic efficiency, e_g = generator efficiency, l_{hydr} = hydraulic losses , l_{trans} = transformer losses, l_{elect} = electrical losses.

During storing and restoration of charge small difference between the output power of generation and the load consumption is accompanied via a battery. 20% to 30% is lost when the mechanical power is converted into electrical power to electricity [10] as shown in figure3.5.Therefore hydro power is capable of converting 80% of natural water energy into electricity irrespective of large energy losses[17,18,19,20] observed in fossil fuelled power plants.

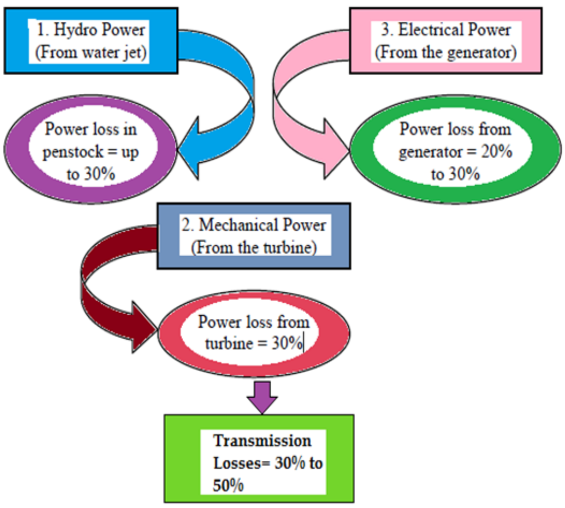

Fig 2.4 - Power loss at different stages of hydro power generation.

III. Implementation

From the Discharge, Potential and Power Calculation it was found that Rainfall data of Jabalpur, Bhopal, Indore, Mawsynram and Goa can be investigated for RWH for Pico Hydro Power Generation. This can be done by iterative procedure of calculation and successively changing the Head.

3.1 Estimation of Power Potential for the place of Jabalpur district of M.P

Volume of water per day for 6000sq feet area comprising 4 flats

Discharge (Q1) = Floor area × highest rainfall

Q1 = 856.7550 m^3/month ……discharge for highest rainfall reading in month of august for Jabalpur rainfall reading of 2012

Q2 = 0.0099 m^3/sec

At Height= 19m

Power= ρ Q g H

Power= 221.7925 KW

Similarly taking the different height= 20m, 40m,50m and 60m power is calculated as

Power for 60m height= 700.3972 KW

3.2 Estimation of power potential for different places of India

By similar calculation it would be tedious to calculate places like Bhopal, Indore, Mawsynram and the Goa etc so through mat lab programming an iterative procedure has been applied for RWH system by the following method

3.2.1 Simplified Under-Relaxed Procedure applied for RWH system

The proposed iterative procedure consists of the following steps

Step 1) R=19…………………Iteration Counter
Initialize $(height^R)_{pq}$

Step *2)* Build $Ø^R{}_{pq}(_{pq})$.

Step 3) Solve SHSP with p_{pq} = $Ø^u{}_{pq}(Qmax\ _{pq})$,

Step 4**)** Update $(height^R)\ _{pq}$. If convergence has not been reached, increase the iteration counter, (u=u+l) and go to Step2.

By applying the iteration counters it was investigated that at maximum height maximum potential of power is achieved and its sustainability is found out by comparing the data of Nepal where Height was taken as 18m. So the constant height parameters for individual multies were updated from 19m to 60 meters .

IV. Result

MATLAB became a standard tool for flexible technical computing and Simulink became an interactive tool for modeling, simulating, and analyzing these dynamic systems. Simulink offers a set of tools that can be used to build complicated systems from a library of built-in blocks Fig. 4.1. The analysis that was carried out during this study was for different places of India (and graph was plotted between the height and the available power shown in fig 4.1.

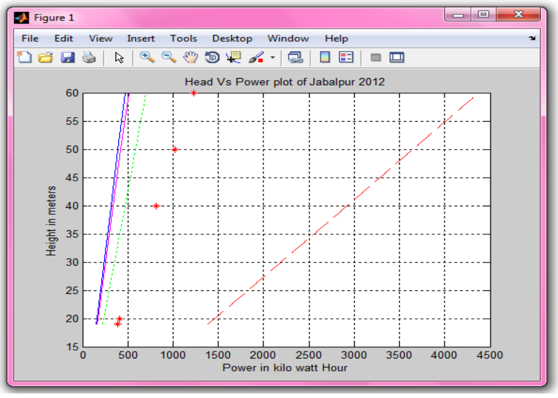

Fig 4.1

4.2. Second analysis was the main characteristic curves for pelton wheel are obtained keeping Height and discharge constant as shown in fig 4.2 and 4.3

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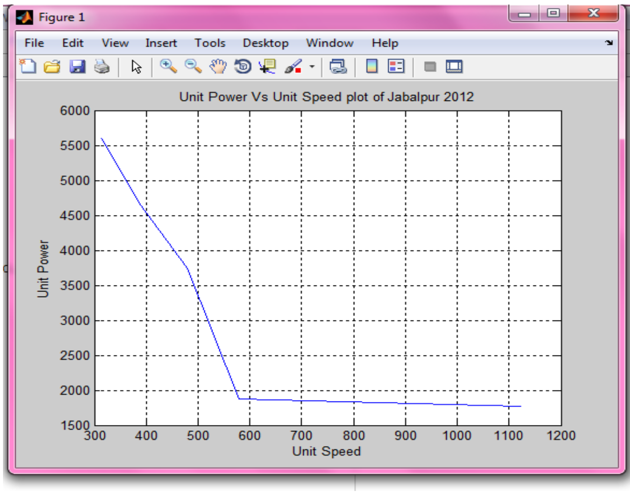

Fig 4.2

S.No	Parameters	Min Value (Jabalpur M.P)	Max Value (Jabalpur M.P)	Nepal
1	Height (m)	19 meters	60 meters	18 meters
2	Discharge		0.01m^3/sec	1.5 lit/sec
3	Power	221.7925 KWh	700.3972 KWh	105 Watt
4	Diameter of jet(d)	2.5cm	1.9cm	0.732cm
5	Velocity of jet(u)	8.69 m/sec	15.44 m/sec	18 m/sec
6	Velocity of wheel(V)	18.92 m/sec	33.62 m/sec	8.59 m/sec
7	No of jets	2	10	2
8	Hydraulic Efficiency		78%	70%

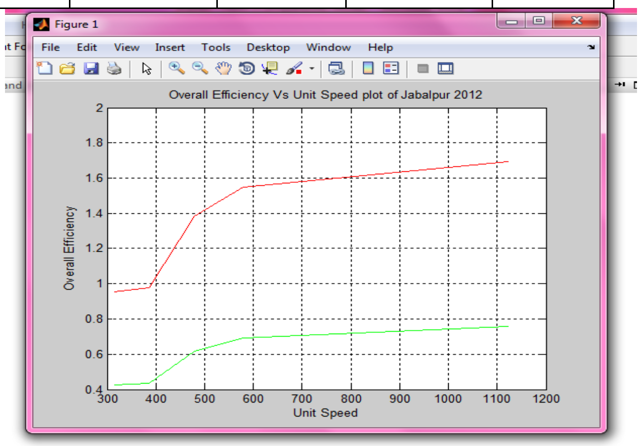

Fig 4.3

4.3 Generation Scheme Design

The generation scheme of Pico Hydro was designed and developed by using MATLAB /SIMULINK software as shown in figure 4.4

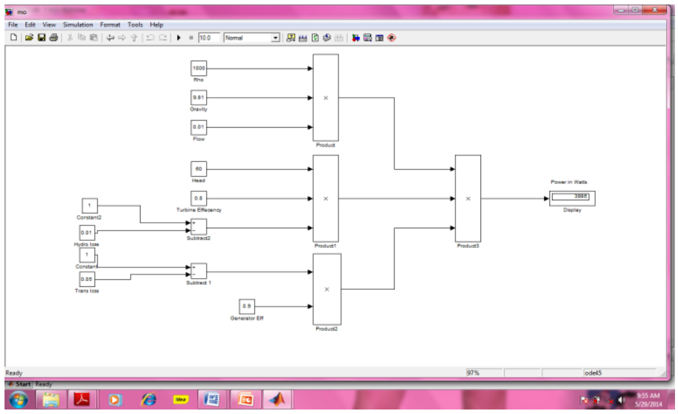

Fig 4.4

Pico Hydro power generation = SHP (KW) × (ηh)
= (5651.522/1000) × 0.78
= 4.408 KW

V. CONCLUSION

From this study, the operation work of the Pico-hydro System for RWH can be understood from the first pace of taking the rainfall data and determining the head of the proposed project. Then calculate the efficiencies of the water turbine and thereby finally calculate the plant capacity of the Pico-hydro System.

It was found that the most useful and the most appropriate water turbine that can be used for the Pico-hydro system for RWH system (78%).

VI. FUTURE WORK

With the aid of fluid dynamics, parameters like losses in pipes, windage in the Pelton housing, pipe division ('Y') for double nozzle, performance variation with GI pipe or aluminum chrome PV pipes can be studied for further improvement of the system.

VI. REFERENCES

[1]Renewables2011,GlobalStatusReport:www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf

[2] Bali Climate Change Conference - December 2007, United Nations Framework Convention on Climate Change: http://unfccc.int/meetings/bali_dec_2007/meeting/6319.php.

[3] Li Wang, Dong-Jing Lee, "A Micro Hydro Power Generation System for Sustainable Microgrid Development in Rural Electrification of Africa" *Power and Energy Society General Meeting, 2009 IEEE.*

[4] Mohibullah, Mohd. Amran Mohd. Radzi and Mohd Iqbal Abdul Hakim,"Basic Design Aspects of Micro Hydro Power Plant and Its Potential Development in Malaysia" *Power and Energy Conference, 2004. Proceedings. National. IEEE.*

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[5] Arun Kumar and Vinay Shankar, "SHP Development In India", 5th Hydro Power for Today Forum, May 11-12, 2009, Hangzhou, China.

[6] Arun Kumar, "Small Hydropower Development: Recent Indian Initiatives" International Conference Water India-V, New Delhi, Nov 3-4, 2008.

[7] Central Electricity Authority, Hydro Development Plan for 12th Five Year Plan, New Delhi, Sept 2008.

[8] Central Electricity Authority, Power Scenario at a Glance, , Central electricity Authority, New Delhi, April 2010.

[9] A. Harvey, A. Brown, P. Hettiarachi and A. Inversin, "*Micro hydro design manual: A guide to small-scale water power schemes*," Intermediate Technology Publications, 1993.

[10] P. Maher and N. Smith, "Pico Hydro for Village Power: A Practical Manual for Schemes up to 5 kW in Hilly Areas," 2nd ed., Intermediate Technology Publications, May 2001.

[11] Fladerer Thomas: *Der Asynchrongenerator im Kleinkraftwerk*. Availabe at: www.flender.com/_upload/asynchrongenerator_kleinkraftwerk.pdf.

[12] G. **W.** Chang, I. ***G.*** Waight, I. Medinq M. Aganagic, **S.** Reeves T. Burton, and M. Christoforidis "Experiences With Mixed Intcger Linear Programming Based Approaches on Short-Tam Hydro Scheduling," *IEEE Transaction on power system, vol.* 16, pp. 743-749, 2001

[13]http://books.google.co.in/books/about/A_Text_Book_of_Fluid_Mechanics_and_Hydra.html?id=nCnifcUdNp4C

[14] H. Zainuddin, M. S. Yahaya, J. M. Lazi, M. F. M. Basar and Z. Ibrahim, "Design and Development of Pico-hydro Generation System for Energy Storage Using Consuming Water Distributed to Houses." *World Academy of Science, Engineering and Technology, Issue 59, pp. 154-59, November 2009.*

[15] http://homepower.com/basics/hydro.

[16] Sebastian Hermann, "Design of a Micro-hydro Powered Battery Charging System for Rural Village Electrification", Master Thesis Postgraduate Programme Renewable Energy, Energy and Semiconductor Research Laboratory, Department of Physics, Faculty of Mathematics & Science, Carl von Ossietzky University Oldenburg / Germany, Bandung, Cottbus & Oldenburg, March 2006.

[17] Ministry of power, Government of India 2010 (www.powermin.nic.in).

[18] Central Electricity Authority, New Delhi (www.cea.nic.in).

[19] Sectoral Overview Report on Hydropower Development in India, AHEC, IIT Roorkee, February 2007.

[20] P. Saxena and Arun Kumar, "Small hydropower development in India", special publication 25 years of Renewable Energy in India, MNRE, New Delhi, 2007.

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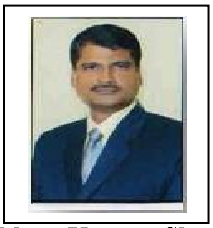

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