ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 6 , June 2018

Hydraulic Analysis and Modelling of Small Hydro Power: A Case Study of a Plant at Gogripur, Karnal

Satish Kumar Kadian, Dr. J.P. Kesari , Dr. R.S. Mishra

M.Tech. Student, Department of Mechanical Engineering, Delhi Technological University
Associate Professor, Department of Mechanical Engineering, Delhi Technological University
Professor, Department of Mechanical Engineering, Delhi Technological University

ABSTRACT: India's renewable energy sector has an estimated renewable energy potential of about 900 GW from sources like wind – 102 GW, Bio energy – 25 GW, Small hydro – 20 GW and Solar power – 750 GW. Renewable energy enjoys 20% shares of total installed capacity of 69022 W in India as on 31 March 2018. Small hydro is the development of hydro electric power on a scale suitable for local community and industry. Most hydro electric powers from the potential energy of dammed water driving a water turbines and generator. This paper discusses the potential of hydropower, renewable energy in India and case study of a small hydro plant at Gogripur, Karnal.

KEYWORDS: Head, Flow, Renewable energy, Potential, Kalpan, Turbine, Efficiency

I. INTRODUCTION

Renewable energy sources (RES) that use indigenous resources have the potential to provide energy with negligible emissions of air pollutants and greenhouse gases. Renewable energy technologies produce marketable energy by converting natural phenomena or resources into useful energies. The usage of renewable energy resources is a promising prospect for the future as an alternative to conventional energy. Therefore, an attempt has been made through to review the availability of renewable energy options in India, and provides information about the current status of renewable, future potentials of their uses, major achievements, and current government policies, delivery and outreach in Indian context. It paints a remarkable overall picture of renewable energy resources and position of India on global map in utilizing these resources.

Renewable energy supplies 18% of the world's final energy consumption counting traditional biomass, large hydropower, and "new" renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels). New renewables represents 2.4% and are growing very rapidly in developed countries and in some developing countries. Global renewable energy capacity grew at rates of 15-30% annually.

II. THE RENEWABLE ENERGY POTENTIAL AND HYDRO POWER POTENTIAL IN INDIA

The role of new and renewable energy has been assuming increasing significance in recent times with the growing concern for the country's energy security. The renewable energy industry has approximately USD 500 million as turnover, the investment being' about USD 3 billion. Of the estimated potential of approx. 10,00,000 MW from RE only about 69022 MW has been exploited to date. Current installed capacity hydro power is 45,403 MW which is more than 26% of the assessed potential. In the beginning of year 2018, the total installed capacity of electrical energy from all sources is 3,43,778 MW.

India has set a new target of achieving 175 GW from all renewable sources and out of which 100 GW is from solar power alone by 2022. Four of the top seven largest solar plants worldwide are in India including the second largest solar park in the world at Kurnool, Andhra Pradesh, with a capacity of 1000 MW[17] India at the centre of its "Sunshine Countries" International Solar Alliance project promoting the growth and development of solar power internationally to over 120 countries. India set a target of achieving 40% of its total electricity generation from non-fossil fuel sources by 2030, as stated in its Intended Nationally Determined Contributions statement in the Paris

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 6 , June 2018

Agreement[16]. The estimated potential for power generation in the country from small hydro plants is about 20,000 MW. The mission aims is that at least 50% of the potential in the country is harnessed in the next 10 years[18]. The public sector accounts for 92.5% of India's hydroelectric power production. The National Hydroelectric Power Corporation (NHPC), Northeast Electric Power Company (NEEPCO), Satluj Jal Vidyut Nigam (SJVNL), THDC, and NTPC-Hydro are some of the public sector companies producing hydroelectric power in India. The private sector is also expected to grow with the development of hydroelectric energy in the Himalayan mountain ranges and in the northeast of India[14]. A map is given below to show major hydroelectric plants in India.

III. MODELLING OF HYDRO POWER PLANT

Cost effective and efficient project we need to study the optimal selection of hydro turbine.An analysis of cost of electro-mechanical equipment for small hydropower has been made and a co-relation is developed[8,9]. The power availability will change the livelihood of the villagers, resulting into creation of jobs such as small business enterprises. This will add some income to the village community[5].

A. Flow analysis

Thus by using the Bernoulli's equation to analyze the fluid flow from point 1 to point 2 as used by Kelly. J.R for the Euler's equation to obtain Bernoulli's equation by integrating along a streamline for steady, incompressible, frictionless flow which gives to Eq. 3.1.

$$H = \frac{p}{pg} + \frac{v^2}{2g} + z \tag{3.1}$$

Where;$\frac{p}{pg}$= the head due to local static pressure, $\frac{v^2}{2g}$ = the head due to local dynamic pressure, Z = the elevation head, H = the head for the flow.

From Eq.3.1;

$$H = \frac{p}{pg} + \frac{vr^2}{2g} + z_1 = \frac{pn}{pg} + \frac{vn^2}{2g} + z_n \tag{3.2}$$

At the surface of the river bed, the fluid moves very slowly compared to the flow along the pipe. We say that $u_r = 0$, Also the pressure is atmospheric pressure, $p_r = p_n$ = Patomspheric. $Z_r - Z_n$ is the elevation of the river bed and the turbine.

$$Z_r = \frac{vn^2}{2g} + Z_n \tag{3.3}$$

$$Z_r - Z_n - H_f = \frac{vn^2}{2g} \tag{3.4}$$

The velocity is the velocity of the water jet at the nozzle. The pressure head at point 1 and 2 is equal to zero.

From Eq. 3.4, $$Z_r - Z_n - H_f = \frac{vn^2}{2g};\ v_n\left(\frac{M}{S}\right) = \sqrt{2xg\,(Z(m) - Z_m - H_f} \tag{3.5}$$

Where; V_n is the same as $V_1 H_f$ is equal to f L/d_{pipe} × $\frac{vn^2}{2g}$. therefore the flow rate entering the turbine from the nozzle is expressed as Q = AV.

$$Q = V \times A = V \times \frac{\pi d^2}{4} \tag{3.6}$$

Power at turbine wheel:

$$\text{Power}[\,P] = \rho g Q H \tag{3.7}$$

B. Terminology used

(i) tangential velocity[u] = $\frac{\pi \times D_M \times N}{60}$

(ii) flow rate [Q] = $\frac{\pi\left(D_2^2 - D_1^1\right)}{4} \times vf$

(iii) absolute velocity [v] = $\sqrt{2g\ \ H_{net}}$

(iv) Flow Ratio = $\frac{v(\,f\,)}{v}$

(v) Speed ratio = $\frac{u}{v}$

(vi) specific speed of time [Ns] = $\frac{N \times \sqrt{P}}{H^{5/4}}$

(vii) Overall efficiency [N0] = $\frac{H_{turbine}}{H_{net}}$

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 6 , June 2018

(viii) Power = $\rho g Q H_{turbine}$

C. Analysis of axial flow turbine

Analysis procedure for axial flow turbine was done. Let for Kalpan turbine suffixes 1 and 2 denote inlet and outlet conditions respectively. Thus, for example D_1 represents the inlet location at the tip of the runner. (Since for a Kaplan turbine, D_1= D = D_2, in the diameter of the runner of a Kaplan propeller turbine is consistently referred to as D_1). The flow in axial through the blades.

Area of flow $A = \frac{\pi}{4}(D_1^2 - D_h^2)K_1$ where $K_1$is the net area factor after deducting for the area occupied by the blades in the cross section. For preliminary studies, it is usual to take K_1= 1.0.

$$\text{Area of flow } A = \frac{\pi}{4}(D_1^2 - D_h^2) \tag{3.8}$$

$$\text{Discharge } Q = \frac{\pi}{4}(D_1^2 - D_h^2)V_{f1} \tag{3.9}$$

V_{f1}= V_{f2} = Velocity of flow which is taken as constant in the entire inlet-outlet space, i.e. all along the inlet radius as well as all along the outlet radius.

Let u_1 = Peripheral velocity an inlet at any radius r, and u_2 = Peripheral velocity at the outlet at the same radius r. Then

$$u_1 = u_2 = u = \frac{2\pi r N}{60} \tag{3.10}$$

The flow is assumed to leave the runner axially without any whirl component. Thus, at the outlet α_2 = 90° and V_2 = V_{f2}, as used in the case of a Francis turbine.

It is assumed that the flow entering the whirl chamber from the guide vanes creates a free vortex in the whirl and runner chambers where the velocity is inversely proportional to the radius. Thus, if $r_h = (D_h/2)$ is the radial distance of the hub from the axis, $r_t = (D_1/2)$ is the radial distance of the blade tip and $r_m$is the radial distance of the midpoint of the blade then

$$(V_{u1})_t r_t = (V_{u1})_m r_m = (V_{u1})_h r_h = \text{Constant} \tag{3.11}$$

In this $(V_{u1})_x$is the velocity of whirl at the given radius x on the inlet side of the blade.

The Euler equation is applicable given in Euler head $H_e$as

$$H_e \frac{V_{u1}u_1 - V_{u2}u_2}{g} = \frac{V_{u1}u_1}{g} = \quad (\therefore\ V_{u1} = 0) \tag{3.12}$$

Further, the hydraulic efficiency

$$\eta_h = \frac{H_e}{H} = \frac{V_{u1}u_1}{gH} \quad \text{[where H = Net head]} \tag{3.12a}$$

IV. CASE STUDY OF A SMALL HYDRO POWER PLANT AT GOGRIPUR, KARNAL

Gogripur is a village situated in Karnal district of Haryana. It is along the left bank of WYC canal about 3 km from Karnal town. The small Hydro power plant was set up in Gogripur by Haryana Renewable Energy Development Agency (HREDA) through P&RGogripur Hydro Power Private Ltd. The small hydro power plant has 2 turbines both are operational. The small hydro power plant has the capacity of 2000 KW (2 MW) where each unit have 1000 KW capacity. The main purpose of the plant is to generate electrical energy through sustainable means by exploiting the potential energy of the flowing water for power generation. It leads to a cleaner environment through lower greenhouse gas emissions and other pollutants and greater security of the nation through lower fuel consumption, fossil fuel conservation for other activities. As it generates electricity through sustainable means, it will not cause any negative impact on the environment and there by contribute to climate change mitigation efforts. The total gross generation potential is 11913.60MWhbased on 75% dependable year. The generated power is supplied to the grid by connecting it with HAREDA transmission lines.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 6 , June 2018

Generating Units
A. Turbine

- Type : **Semi kaplan**
- Shaft : **Vertical**
- Rated discharge : **68.3 m^3/s**
- Rated output : **1000 kW each unit**
- Rated speed : **110 rpm**
- Number of generating units : **2**

B. Generator

- Type (Synchronous / induction) : **Synchronous**
- Rated speed : **110 rpm**
- Overload : **10%**
- Frequency : **50 Hz**
- Generation Voltage : 66.5 kva
- Power factor : **0.8**

C. Power Evacuation:

- Transmission voltage (grid) : **33 kV**
- Transmission line : **11 kV**

By using EES software program using EES software and by using different mathematical equations to determine the overall efficiency of the Gogripur small hydro power plants. Hence input parameters such as tangential velocity, flow rate, absolute velocity flow ratio, speed ratio, specific speed of turbine, and head of turbine are calculated to obtain the overall efficiency.

The following curves were obtained by ESS software:

Figure 1.1,shows the flow rate against the net head as, the head increases from 2m to 4m. The volumetric flow rate was decreasing from 95 m3/sec to 47 m3/sec as the volume of water decreases the pressure is increased. This increase in pressure influences the power delivered to wheal by jet of water.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 6 , June 2018

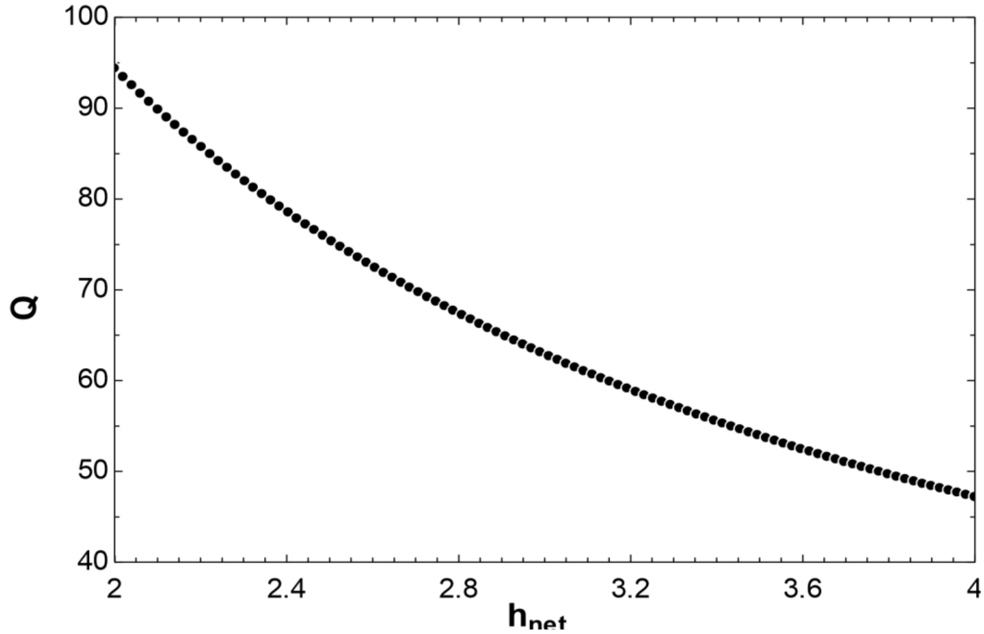

Figure 1.1: Flow rate (m^3/s) versus Net head (m)

Figure 1.2, shows the head of turbine is directly proportional to the net head. Thus head of the turbine was increased with the increase of net head from 2m to 4m and vice versa.

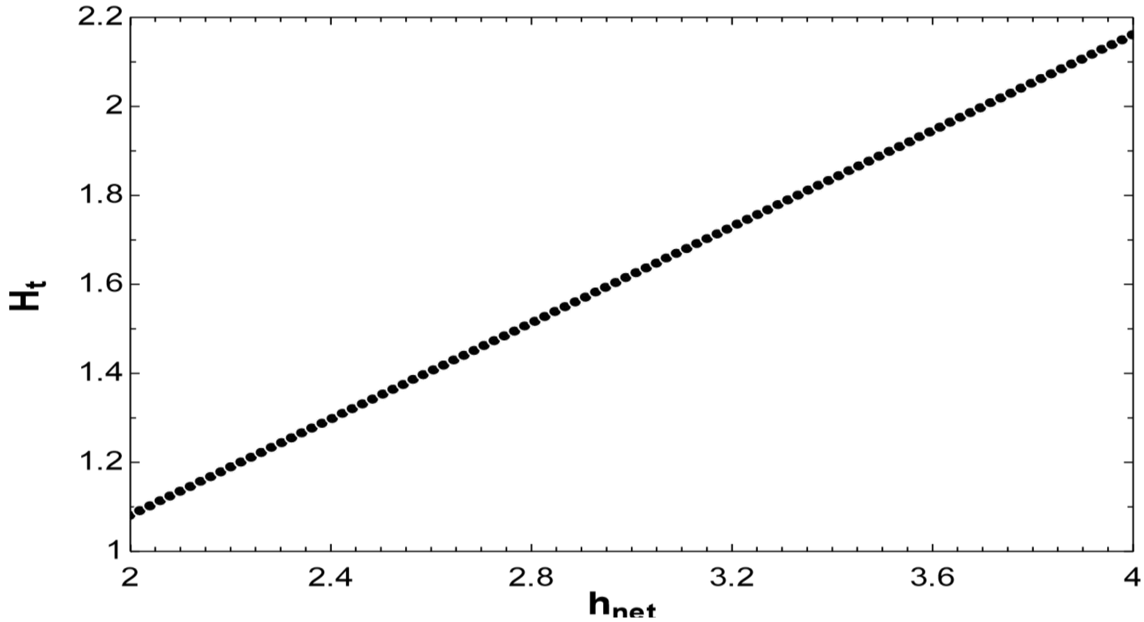

Figure 1.2: Turbine Head (m) versus Net head (m)

Figure 1.3, shows the overall efficiency of power plant decrease from 0.75% to 0.38% with increased net head from 2m to 4m respectively. Hence, the power load factor of power plant decreases.

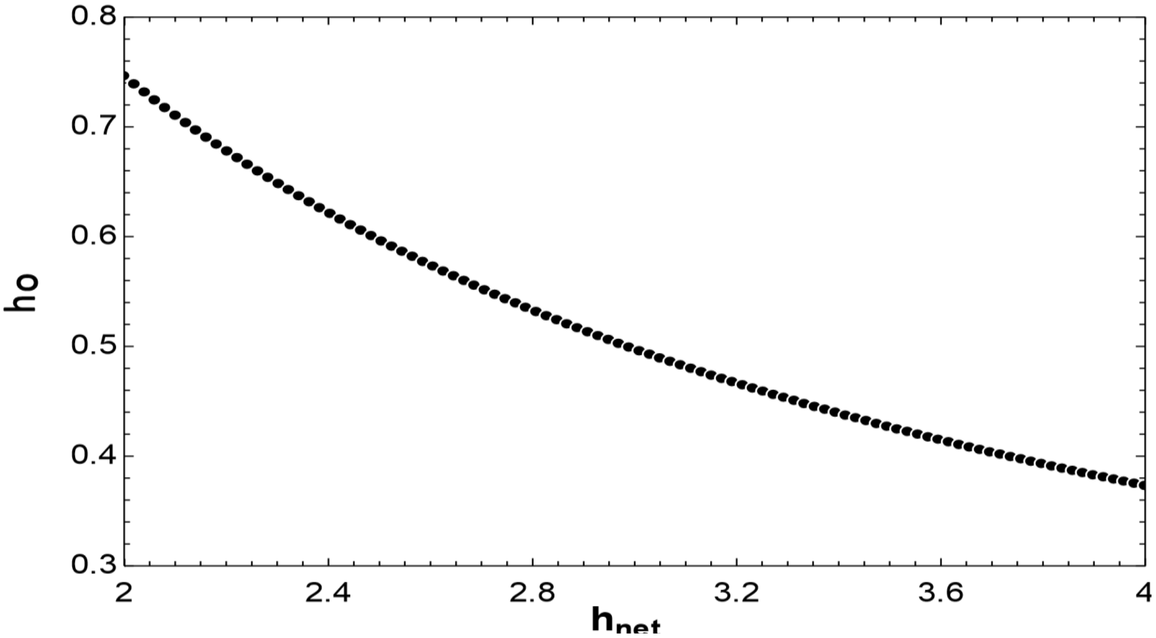

Figure 1.3: Overall efficiency (%) versus net head (m)

Figure 1.4, shows similarly the overall efficiency of the power plant decreases from 0.75% to 0.38% with the increased flow rate from 50m3/sec to 100 m3/sec. Thus here also the power load factor of the power plant decreases.

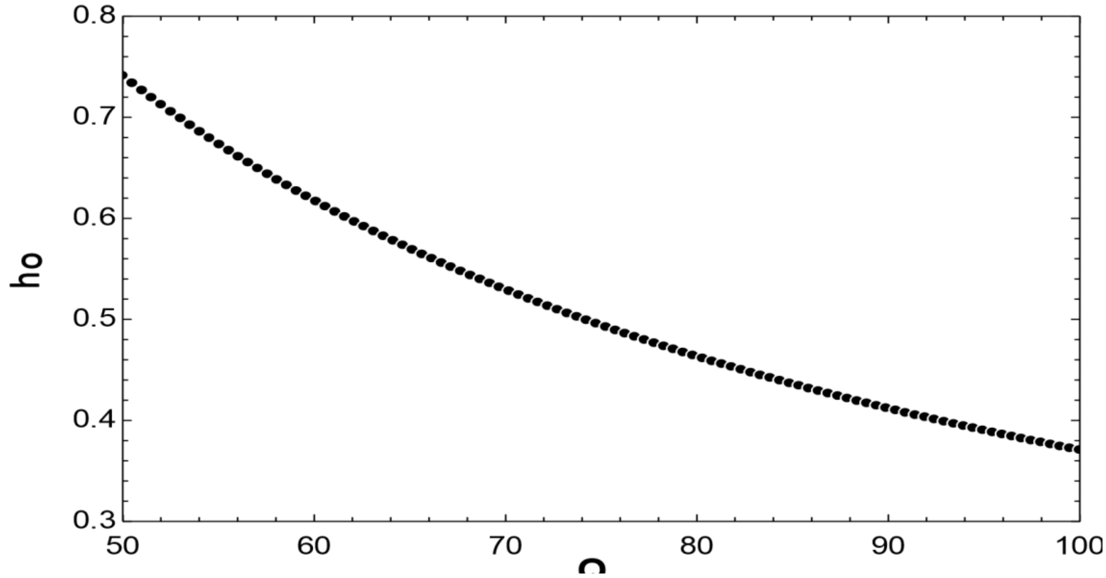

Figure 1.4: Overall efficiency (%) versus flow rate (m^3/s)

Figure 1.5, shows as the flow rate increases with decreased elevation, the power delivered to the wheal is decreased as the elevation decreased from 2m to 1.2m by increasing the flow rate from 50m3/sec to 100m3/sec.

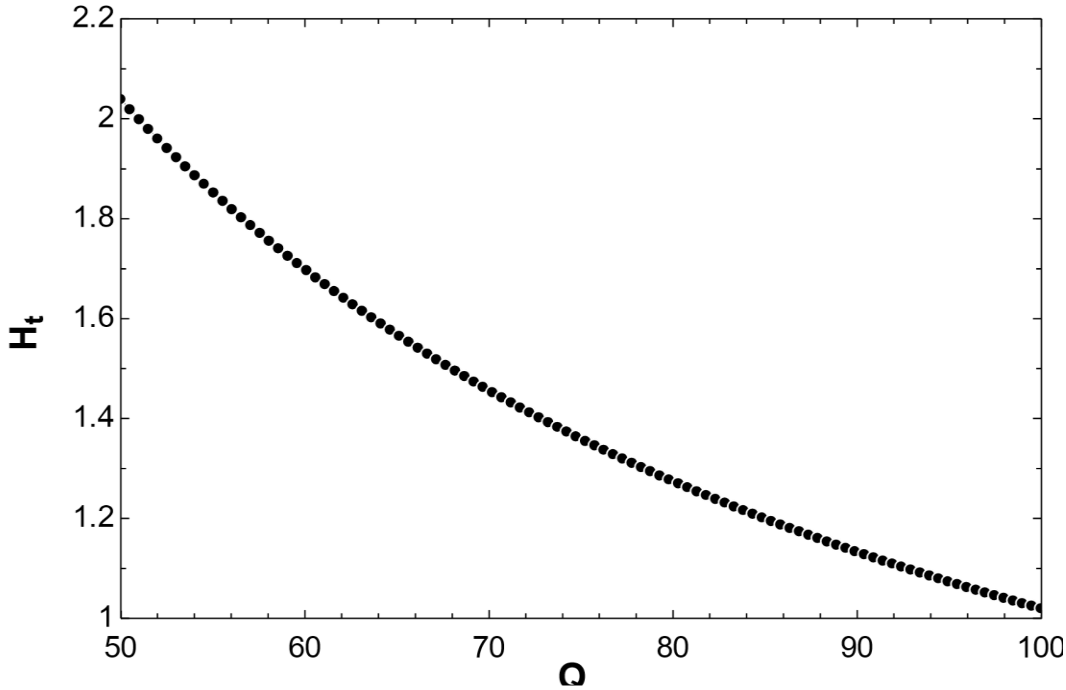

Figure 1.5: turbine head (m) versus flow rate (m^3/s)

Therefore, after the discussion of all the figures from 1.1 to 1.5 and consider their results outputs and there after carry out various calculation as shown above, we comes to the result that the overall efficiency of the power plant is 54.5% and hence the power load factor is also 54.5%.

V. CONCLUSION

The research work investigated by doing head and flow analysis on the 2 MW Gogripur, hydro power plant to calculate the overall efficiency hydro power plant. The analysis was presented by EES computer program. The Kaplan turbine operating on small head and high flow condition generated an overall efficiency higher while that of high head and high flow with decreased pressure will generate lesser overall efficiency and could be applied in sitting a small hydro power plant.

The operating condition for the Kaplan turbine is calculated by considering various input parameters i.e. head, flow rate, RPM, power, tangential velocity, absolute velocity are used to calculate and finally obtain the overall efficiency. The flow rate decrease from 100 m^3/s to 50 m^3/s with head and also the head is varied from 2m to 4 m with flow rate. Hence, small head and high flow are recommended for power generation of a small hydro power plant that could help to attain required level of overall efficiency of the plant instead of large head and low flow which is applicable for power generation of a large SHPP.

REFERENCES

[1] National Renewable Energy Laboratory (NREL). 2012. Renewable Electricity Futures Study.
[2] Ales Drab, JaromirRiha& Miroslav Spano (2015). Failures and durability analysis of a small hydro power plant. Institute of Water Structures, Brno University of Technology, Czech Republic.
[3] K.H. Motwani, S.V. Jain , R.N. Patel (2012). Cost analysis of pump as turbine for pico hydropower plants – a case study. Institute of Technology, Ahmedabad, India.
[4] Kelley J. B. (1950). The Extension Bernoulli's Equation. American J. Phys. 202– 204. India.
[5] Miguel M. Umausse, DinisJuizo, Kenneth M. Person (2015). Hydro Power Potential in Mozambique "Chua-Manica". DuardoMondlane University, Maputo, Mozambique.
[6] PimnapatIemsomboon, TrirathPati and KrischonmeBhumkittipich (2012). Performance Study of Micro Hydro Turbine and PV for Electricity Generator, Case Study :Bunnasopit School, Nan Province, Thailand.

[7] S.U. Patel, Prashant N. Pakale (2015). Study on Power Generation by Using Cross Flow Water Turbine in Micro Hydro Power Plant. COE, Shahada, Maharashtra.

[8] Sachin Mishra, S.K. Singal, and D.K. Khatod (2012). Costing of a Small Hydropower Projects. Roorkee, India.

[9] SaurabhSangal, Arpit Garg, Dinesh Kumar (2013). Review of Optimal Selection of Turbines for Hydroelectric Projects. IITRoorkee, India.

[10] Staubli T. et al. (2009). Jet quality and Pelton efficiency. Proceeding of Hydro2009, Lyon, France.

[11] Suraj Y. (2011). Some aspects of performance improvement of Pelton wheel turbine with reengineered blade and auxiliary attachments. International journal of Scientific and Engineering Research. 2(9), 1-4.

[12] Vesely J. and Pochyly F. (2003). Stability of the flow through Pelton turbine nozzles. Hydro-2003, Dubrovnik, Croatia.

[13] “Harnessing gigantic hydro power potential of Indus, Jhelum and Chenab rivers by diverting water to Ravi and Beas rivers”. Retrieved 30 November 2017.

[14] Gajic, A, Cam Characteristics of the Kaplan turbine determined by Efficiency and Bearing Vibrations, 6th International conference on Hyd. Mach. and Hydrodynamics, Romania, 2004.

[15] http://www.cea.nic.in of Central Electricity Authority (CEA), Ministry of Power, Government of India.

[16] “Here are India’s INDC objectives and how much it cost”. The Indian Express 2015-10-02. Retrieved 2017-12-27.

[17] “All India Installed Capacity of Utility Power Stations” (PDF). Retrieved 13 April 2016.

[18] Information related to SHP potential in India can be obtained from the website of the Ministry of New and Renewable Energy, Government of India. See: <⟨https://mnre.gov.in/small-hydro⟩> [accessed20 June 2018]; 2018.

[19] Ashish Kumar, Dr.Kesari, J.P. and Prof. Mishra, R.S (2017). Economic Feasibility, Profitability And Mathematical Analysis of 432 Kw Rooftop Solar Photovoltaic Power Plant, International Journal of Development Research Vol. 07, Issue, 09, pp.14951-14967, September, 2017, ISSN: 2230-9926

[20] Ashish Yadav , Dr. Rajesh Kumar , Dr. J P Kesari , Dr. R S Mishra (2017) Thermo-Economic Analysis of Concentrated Solar Heat Applications in Hospitality Industries, International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 9, September 2017), http://www.ijetae.com/files/Volume7Issue9/IJETAE_0917_ 49.pdf