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Influence of Penstock Outlet Diameter AndTurbine Hub To Blade Ratio on The Performance of A Simplified Pico Hydropower System

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ABSTRACT: A study to determine the effect of penstock outlet and runner hub to blade ratio on the performance of an existing simplified Pico hydro system was been conducted. Five turbine runners with 10 V-shaped blades and hub to blade ratios of 0.7, 0.65, 0.55, 0.4, and 0.3 were fabricated and tested. The turbine was connected to a 3.9 kVA alternator via a V-belt drive and a 1 Hp pump was used to circulate water in the system. The speed of the alternator and turbine shafts were measured, and the water level in the two reservoirs were monitored. The results obtained showed that the Pico hydro system with 0.55 runner hub to blade ratio and 20 mm penstock outlet diameter yielded an alternator shaft speed of 1732 rpm. This corresponds to a computed power output of 5.77 kW. In terms of the loss of the alternator speed compared to the ideal value, the hub to blade ratio of 0.55 also gave the least percentage loss with the corresponding penstock outlet diameter being 25 mm. The parameters all statistically varied significantly at 95% level of confidence. The results are good encouragement in the effort towards implementing the system as an environmentally clean and decentralized source of energy.

Keywords: Alternator shaft speed, decentralized source of energy, environmentally clean, Hub to blade ratio, Penstock outlet diameter, Turbine shaft speed.

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I. INTRODUCTION

The level of energy consumption of any society is a reflection of its development [1]-[4]. Uninterrupted energy supply is vital in the economic growth, progress, and development, as well as poverty eradication and security of any nation [5]-[7]. Future economic growth will depend on the long term availability of energy from sources that are sustainable, affordable, accessible, and environmentally friendly. The standard of living of a given country can be directly related to the per capita energy consumption since it is a measure of the per capita income as well as a measure of the prosperity of a nation [8]-[20].

The challenge of the 21st century is the need for sufficient and sustainable supplies of energy to provide the economic activities required to meet the needs of increasing populations. Hence, energy is a prime agent for wealth creation and economic development. Historical data attest to a strong relationship between availability of energy and economic activities [21]-[26].

Currently the global energy demand is rising fast as population and emerging economies like China and India are growing exponentially with small and medium enterprises springing up. In developing countries of Africa like Nigeria, the International Energy Agency forecasts that energy demand would be 50% higher in 2030 than they are today [1], [20], [27]-[31]. Yet fossil fuels on which the world depends are finite and not environmentally friendly [32]-[36]. There is therefore a gradual drift of the world’s attention to potential renewable energy resources for power generation such as wind, solar and hydropower resources. Renewable energy constitutes about 15% of the world’s energy mix with hydropower making most of it [37]-[50].

The global demand for electricity is continuously growing and a vast majority of the people in developing countries, especially in rural areas, do not have access to electricity. This number keeps increasing despite the rural electrification programs because they are not sufficient to cope with the population growth or the political will in some of the places is not strong enough or absent Availability of useable energy in the form of electricity has gradually assumed an essential component of daily life in all society. Access to electricity is a key to development as it provides light, heat and power for productive uses and communication [24], [51]-[58]. Moreover, despite the fact that about 80% of the world‘s population lives in developing countries, they consume only about 20% of the global commercial energy [7], [21], [48], [59]. The World Bank asserts that most of the world‘s poor people spend more than 12% of their total income on energy, which is more than four times what a middle-income family in the developed world spends [60].

In Nigeria, about 40% households were reported to have access to the national grid with more than 45% not having access to any form of electricity. More than 6% support their access to the grid with standby generators while about another 3% completely relied on them. Furthermore, about 1.1% have access to the rural electrification programs while more than three-quarters of the population still depend on firewood for cooking fuel with about 20% relying on kerosene. This is consequent upon low access to and low reliability of electricity services in Nigeria. An urgent need for efforts for further developments of the overall Nigerian electricity sector as well as rural electrification programs to ensure rapid economic development therefore exists [61]-[75].

Electricity generation also causes massive environmental and social problems. The need therefore exists to change the way energy is produced and used in order to reduce these impacts while providing energy services to the growing population of people who have inadequate or no access to electricity [76]. This energy revolution will require moving from electricity systems based on large-scale fossil fuels, large hydro and nuclear fission plants to options based on renewable sources and massive improvements in the efficiency of production, transportation, storage and use energy [5], [22], [77]-[79].

Water is a good choice among the renewable sources of energy because a small-scale hydropower is a very cost-effective and reliable energy technology for providing clean electricity generation. Hydropower is a renewable, economic, non - polluting and environmentally benign source of energy. It is the most reliable and cost effective renewable source and accounts for about 19% of global electricity production from both large and small power plant [80]-[88].

The world has enormous potential for hydropower generation with numerous hydropower stations built all over the world and a large number of hydropower projects with a capacity above 100, 000 MW currently going on globally, Asia having the largest contribution of around 84, 000 MW [48], [89]-[92]. Nigeria is richly endowed with abundant water resources whose potential is in the region of 14,750 MW of power. About 1980 MW of this potential is explored at Kainji, Jebba and Shiroro hydropower stations, each contributing around 760 MW, 600 MW, and 540 MW respectively, leaving 12,200 MW unexplored [45], [50], [65], [93]-[95]. This implies that only about 14% of the nation's hydropower potential is in use. The country has consistently experienced epileptic power supply partly as a result of its inability to exploit its vast hydropower potential in addition to the fact that the available large hydro power plants are not operating up to installed capacity [32], [85], [96] and [97].

Furthermore, large scale hydro schemes are becoming a challenge due to socio-economic and environmental concerns. Conventional large hydroelectric power plants despite having many advantages over other energy sources have potential negative environmental impacts [98]-[100]. It is not reliable since its operation depends on the hydrological cycle [101] and [102]. Also, global climate change will increase rainfall variability and unpredictability, making hydropower production more undependable. Increased flooding due to global warming also poses a major hazard to the safety of dams [103]. In addition, reservoirs lose storage capacity to sedimentation which in many cases seriously diminish the capacity of dams to generate power. Hydropower projects alter the habitats of aquatic organisms and affected them directly [104]-[111]. Several millions of people are usually forcibly evicted from their homes to make way for dams, losing their land, means livelihood and access to natural resources and enduring irreparable harm to their cultures and communities [112]-[116]. Furthermore, growing evidence suggests that reservoirs emit significant quantities of greenhouse gases especially in the lowland tropics [117]-[119]. Also, there is growing evidence that hydropower is often falsely promoted as cheap and reliable, are prone to cost overruns and often do not produce as much power as predicted [120]. Hence, small hydro schemes (mini, micro and Pico) continue to gain increasing popularity especially in remote areas due to its simplicity in design, ease of operation, low environmental impacts in comparison to larger hydro power scheme [89] and [121]. Furthermore, communities could take advantage of simple drinking water projects or irrigation systems to install small hydro schemes.

Developing a means of applying the advantages of hydropower while significantly minimizing the operational and natural shortcomings is a desirable step. Pico-hydro power provides a very good option. It suits the general characteristics of smarter, smaller systems which can be utilized in locations where larger more conventional systems cannot be optimally located. It has become a very useful option in the Asian developing countries where the topography has imposed great natural barrier to the uptake of more conventional grid – connected energy systems [6], [12], [82], [122]-[126]. In Nepal for instance, 300 Pico hydro schemes constructed by practical action are producing electricity while 900 others are used for mechanical power only [127]. There are many sites suitable for Pico hydro development in Nigeria as in many other African countries but deliberate focus has not been given to its development by articulating realizable policies geared towards achieving solutions to the energy crisis. Moreover, it has been verified that seasonal fluctuations of water levels also affect the operation of the conventional Pico hydro schemes. Low water levels do not allow optimal operation while very high ones can sweep the units away [45], [85] and [128].

In the last decade, Pico hydro has become more prevalent in sub Saharan Africa as well, where electrification rates are some of the world's lowest [129]. Although Nigeria has successfully benefited from large and small scale hydropower to generate electricity little or no efforts are been made towards utilizing hydro generation in the range of micro and Pico hydro systems, despite its available potential. If fully utilized it would contribute remarkably to reducing the energy problems of domestic and commercial consumers in addition to providing a cheap source of power to remote areas where the extension of grid system is comparatively uneconomical [65], [94], [97].

Pico hydro systems like other decentralized systems are not prone to sabotage and terrorist attacks as individuals and communities take responsibility of safeguarding their own facilities. Due to the increased rate of terrorist activity in the country, the need and use for small Pico hydro is feasible due to the fact that power can be generated within the domestic environment, hence increasing energy security as power generation and distribution is being modified and simplified [22], [130]-[132].

While Pico hydro present significant advantages including cost over other methods of electricity generation, its implementation also presents several challenges including a heavy dependence on site specific conditions for scheme design. Off the shelf systems have been designed to reduce the site specific design but this does not completely eliminate the need for technical expertise and periodic maintenance [131], [133]-[136]. Also, besides the requirement of flowing water, the exploitation of hydropower requires civil works which constitute the major cost and electromechanical devices such as a turbine and generator. To further reduce the cost of the technology standard pumps and induction motors could be used in place of conventional generators and turbines [137]. These electromechanical devices play an important role in the determination of the power output and the efficiency of the system.

This study however focuses on the investigation of the effect of penstock outlet and the runner hub to blade ratio on the performance of a simplified Pico hydropower system that has been undergoing development in the Department of Mechanical Engineering, University of Agriculture, Makurdi for about four years now [138]-[143]. It involves an overhead water reservoir with a locally fabricated turbine at its foot and has an underground reservoir. A pump is used for recycling the water; tapered pipes are used as nozzles, PVC pressure pipes as penstocks and an alternator or generator. This study seeks to find the optimum penstock outlets and runner hub to blade ratio that will be suitable for the simplified Pico hydropower system with the aim of improving its performance and provision of additional data for research in this field of study. Generally, the present development will explore all the benefits of a simplified Pico hydro system that concedes control to the user and as a result minimize exposure to sabotage and regional restiveness that has adversely affected power supply in Nigeria.

II. MATERIALS AND METHODS

The set up for this study is basically the same proposed and used first by [143] and [140] with some modifications. The turbine runners were fabricated using the procedure in the previous stages of the study. Five runners were fabricated with varying hub to blade ratios of 0.7, 0.65, 055, 0.4 and 0.3. These ranges of ratios were selected because the prevalent approximate value used in literature is 0.55. Fig. 1 shows the turbine runners used for the study. The 76.2 mm diameter pipe used as the penstock was reduced to outlet diameters of 15, 17.5, 20, 22.5 and 25 mm. these reductions are shown in Fig. 2.

Figure 1. The turbine runners used for the study.

Figure 2. The five penstock outlets used for the study

Following the complete fabrication of the runners, each was assembled in the turbine casing proposed and used by [143] and [140], ensuring free spinning of the shaft and preventing leakages from the turbine. The upper and lower ends of the penstock were then connected to the overhead tank and the reduced outlet respectively. Care was taken to align the turbine runner, casing and the penstock outlet with a clearance of about 15 mm between the runner and penstock outlet. The turbine was coupled to a 3.9 kVA alternator via a toothed V-belt drive. The system consists of a pump and the locally fabricated turbine connected in a closed loop through the PVC piping used as penstock, a 2000 liters overhead tank and about 3000 liters underground reservoir. Fig. 3 shows a picture of the entire system.

The Suction pipe of the pump draws water from the underground reservoir to the overhead tank to create a head. The water is then released from the overhead tank through the penstock and the reduced outlet. The flow through the turbine is regulated using a gate valve installed before entry to the penstock and also before the turbine. The water jet strikes the blades which are attached to the hub, thereby transferring its kinetic energy to the shaft causing the rotary motion of the hub and the shaft assembly. A 0.3 m diameter pulley is connected to the turbine shaft and transmits power to a 0.05 m diameter pulley connected to alternator via a toothed V-belt drive in a step up ratio of about 12:1 causing the rotary motion of the alternator shaft. The water in the turbine casing is exhausted through an outlet port into an underground reservoir from where it is re-cycled to the overhead tank by the pump. The pump is rated 1 Hp with a flow capacity of 50 liters/min. A DT2268 contact type digital tachometer was used to measure the speed of generator and turbine shafts. The water levels in the overhead and underground reservoirs were monitored and each duration of the operation timed. These parameters were used to compute the flow rate. The procedure was repeated for the five turbine runners for each penstock outlet diameter. The data obtained were used to compute the hydraulic power of the system, the alternator shaft speed and the computed power were subjected to analysis of variance at 95 % confidence interval. The product of the flow rate and the net head (QH_n)were also computed for each operation with $H_n$determined by summing up the computed hydraulic losses and deducting them from the gross head available. The percentage departure of the measured alternator shaft speed form the ideal expected values were also estimated and related to the hub to blade ratio as well as to the penstock outlet.

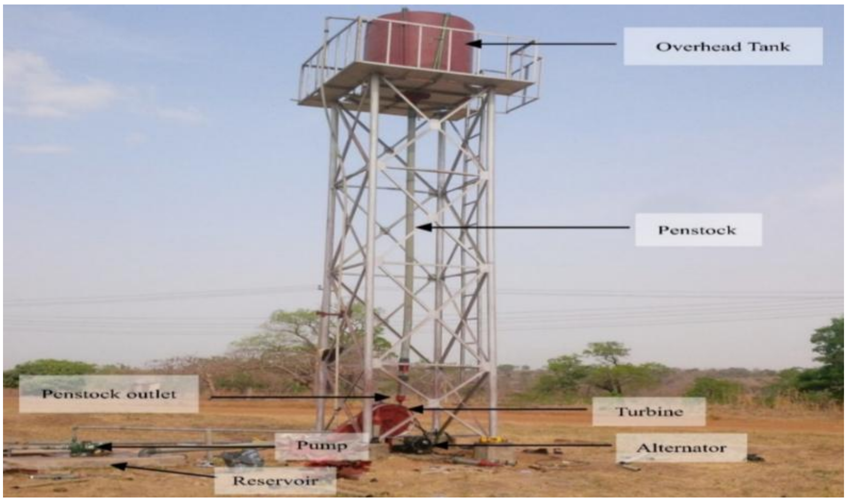

Figure 3. The experimental set up of the system

III. RESULTS AND DISCUSSION

Figs. 4 and 5 depict the variation of the alternator shaft speed (N_A) with the hub to blade ratio (D_h/D_t) and the penstock outlet diameter (POD) respectively. Fig. 4 shows that N_A is maximum for the combination of D_h/D_t and POD of 0.55 and 20 mm respectively. It also shows the dependence of the torque developed by the system on the flow rate which depends on the cross-sectional area of flow. This is indicated by the curves for the POD of 22.5 and 25 mm being next to the one for 20 mm. Fig. 5 confirms the potential high performance of the system with the pair of D_h/D_t and POD mentioned earlier. It further shows that the range $0.65 \geq D_h/D_t \geq 0.4$ will potentially enhance the development of large output power since N_A directly affects the power developed by a hydropower system [22], [144]-[154].

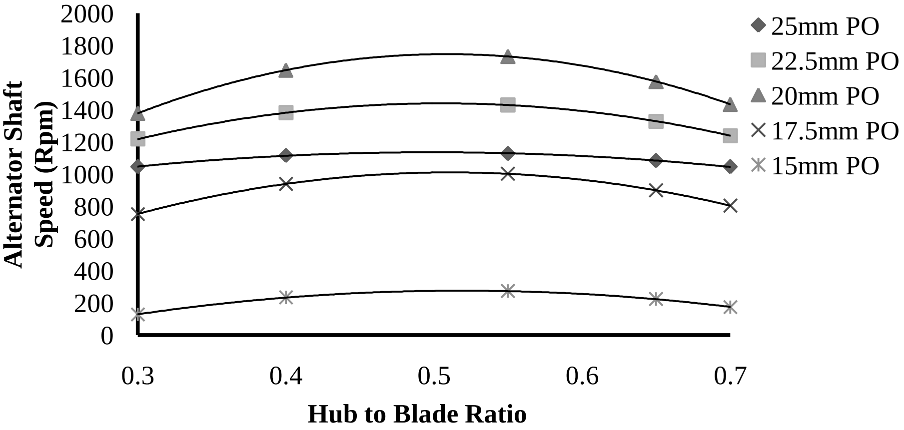

Figure 4. Variation of alternator shaft speed with hub to blade for various penstock outlet diameters.

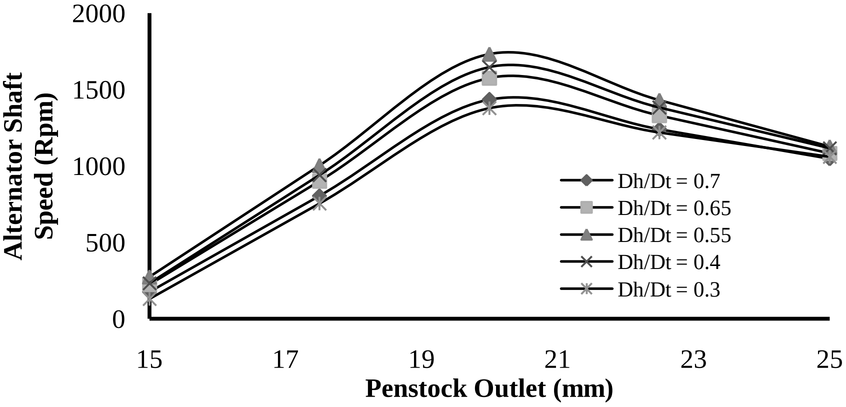

Figure 5. Variation of Alternator Shaft Speed with the Penstock outlet diameters for various Hub to Blade Ratio.

Figs. 6 and 7 show the variation of the computed power with D_h/D_t and POD respectively. Fig. 6 clearly shows that the computed power was maximum for the same combination of D_h/D_t and POD (0.55 and 20 mm) mentioned earlier. The value of the computed power for this combination was in the region of 5.77 kW. This directly derives from the fact that this combination of parameters yielded the highest value of N_A since the power developed depends on the torque on the shaft [6], [155] and [156]. The figure also strengthens the fact that reduction in flow cross-sectional area is detrimental to system performance [157] and [158].

Fig. 7 emphasizes the forgoing explanation. The curves in this figure bare very close similarity to those in Fig. 5. This is because N_A directly affects the power generated. The clustering of the curves indicates that for each POD, the power developed did not vary over a wide range. However, the range is wider for the 20 mm POD which also consolidates the position that this value of POD and $D_h/D_t = 0.55$ is conducive for generating large power outputs with this system.

Figs. 8 and 9 show the variation of the percentage loss in the measured N_A compared to the ideal value with D_h/D_t and POD respectively. In Fig. 8, the general pattern of the trends for all the values of POD indicate that the losses were minimum for $D_h/D_t = 0.55$. The losses increased either side of this value of D_h/D_t confirming the assertion of several researchers that the optimum value of the ratio is around 0.55 [154], [159]-[164].

Fig. 9 generally reinforces the lines of thought in the preceding section. The curves for $0.65 \geq D_h/D_t \geq 0.4$had the lower percentage losses while the ones for $D_h/D_t = 0.3$ and 0.7 depict larger losses. This could be as a result of variations in the masses of the runners as D_h/D_t changes with all the inertial effects. The figure also shows that the POD of 25 mm generally supported the least losses for all D_h/D_t values. This is obviously as a result of the higher flow rates involved which could have reduced the tendency of the losses.

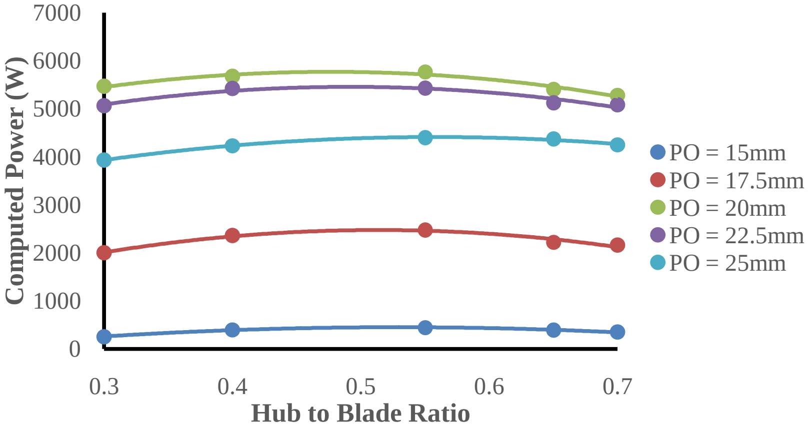

Figure 6. Variation of computed power with the hub to blade ratios for the penstock outlet diameters.

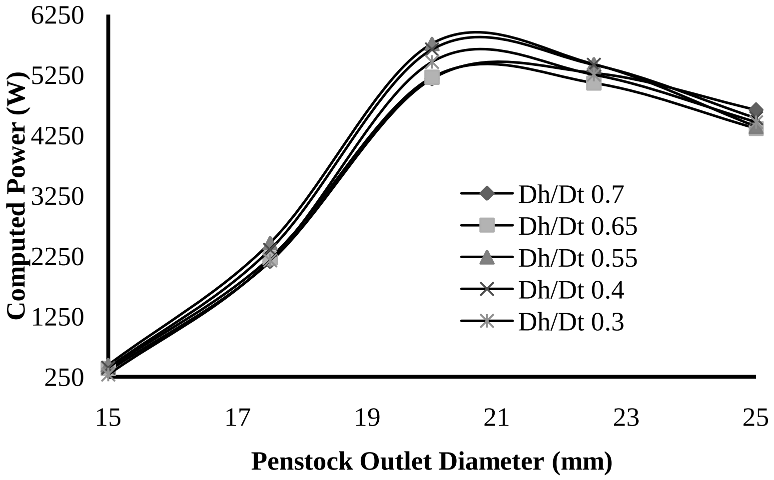

Figure 7. Variation of computed power with the penstock outlet diameter for various hub to blade ratios

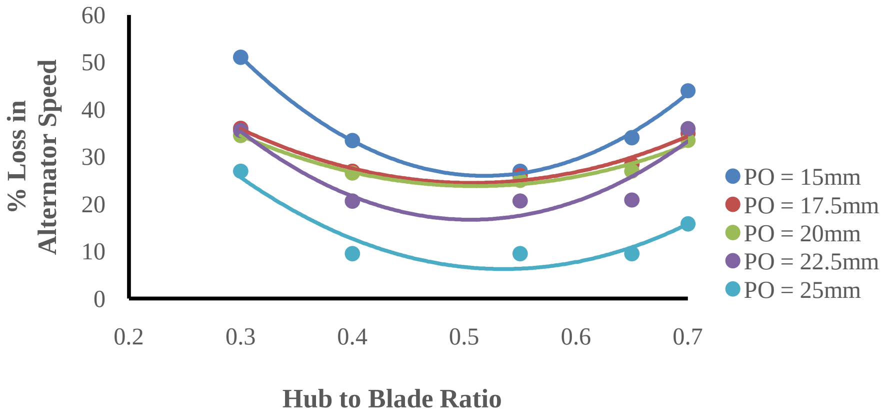

Figure 8. Variation of percentage loss in alternator shaft speed with hub to blade ratio

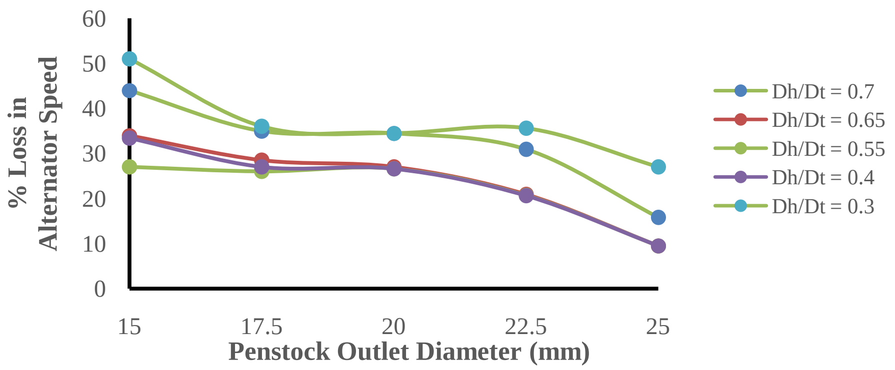

Figure 9. Variation of percentage loss in alternator shaft speed with penstock outlet diameter.

Figs. 10 and 11 show the variation of the flow rate and net head product (QH_n) with D_h/D_t and POD respectively. The parameter QH_n was computed since the flow rate and net head available are critical requisite parameters for building conventional hydropower plants. Moreover, QH_n is part of the analytical expression used for computing the hydraulic power of a hydropower system [159], [165]-[174]. Expectedly, QH_n values were higher for larger POD values as shown in Fig. 10 because flow rate increases with flow cross-sectional area. The variation of QH_n with D_h/D_t as shown in the figure is not very pronounced for each POD. This again is expected because the flow rate and net head are measured parameters and do not depend of the dimensions of the turbine. Fig. 11 shows more clearly the dependence QH_n on POD while emphasizing the slight variation of the parameter with D_h/D_t as shown by the clustering of the trend lines.

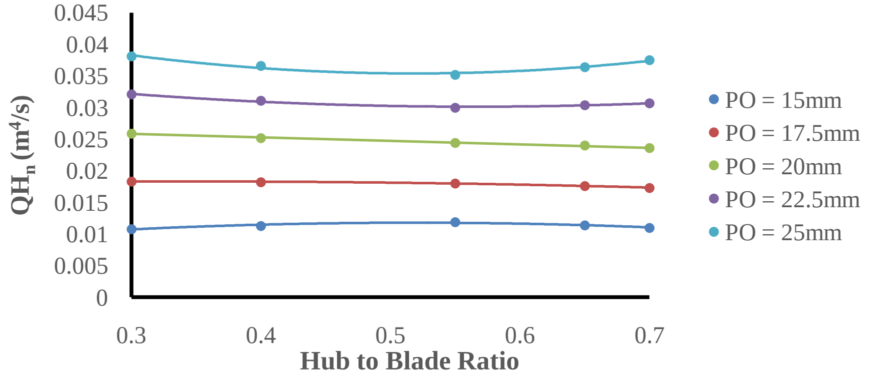

Figure 10: Variation of the flow rate and net head product with hub to blade ratio

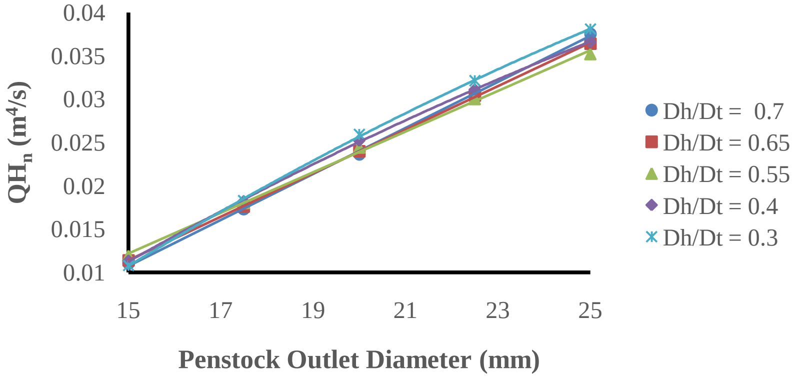

Figure 11. Variation of the flow rate and net head product with penstock outlet diameter.

Tables 1 and 2 show the results of the analysis of variance (ANOVA) at 95% confidence level ofN_A based on D_h/D_t and POD respectively. Table 1 shows that N_A statistically varies highly significantly with POD but much less significantly with D_h/D_t. The results in Table 2 confirm the results in Table 1. The result give statistical credence to the earlier discussion on the variation of the parameters.

Table 1. ANOVA for Alternator Shaft Speed based on Hub to Blade Ratio

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	144706.5	4	36176.62	18.13707	8.58E-06	3.006917
Columns	5290375	4	1322594	663.0796	1.5E-17	3.006917
Error	31913.96	16	1994.623			
Total	5466995	24				

Table 2. ANOVA for Alternator Shaft Speed based on PenstockOutlet Diameter

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	5304354	4	1326088	588.9328	3.84E-17	3.006917
Columns	155212.8	4	38803.19	17.23299	1.19E-05	3.006917
Error	36026.89	16	2251.68			
Total	5495594	24				

Tables 3 and 4 show the results of ANOVA of computed power with D_h/D_t and POD respectively at the same confidence level. Table 3 shows that the power varies very significantly with POD but the variation with D_h/D_t is not statistically significant. However, Table 4 shows a slightly significant variation with D_h/D_t suggesting that the power also depends on it.

Table 3. ANOVA for Computed Power based on Hub to Blade Ratio

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	216018.2	4	54004.55	3.15295	0.043286	3.006917
Columns	96465432	4	24116358	1407.986	3.72E-20	3.006917
Error	274052.2	16	17128.26			
Total	96955503	24				

Table 4. ANOVA for Computed Power based on Penstock Outlet Diameter

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	96108471	4	24027118	1869.375	3.88E-21	3.006917
Columns	242761.2	4	60690.3	4.721869	0.010433	3.006917
Error	205648.4	16	12853.02			
Total	96556881	24				

Tables 5 and 6 shows the results of ANOVA for the loss percent in the measured N_A with D_h/D_t and POD respectively. The tables show that the loss percent slightly statistically affect both parameters at the same level of confidence. Hence, in addition to other structural and operational errors, the right combination of D_h/D_t and POD is essential for improving the efficiency of operation of the system.

Table 5: ANOVA for Percentage Loss of Alternator Shaft Speed based on Hub to Blade Ratio

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	1334.814	4	333.7034	7.495685	0.001336	3.006917
Columns	1235.678	4	308.9194	6.938984	0.001942	3.006917
Error	712.3104	16	44.5194			
Total	3282.802	24				

Table 6: ANOVA for Percentage Loss of Alternator Shaft Speed based on Penstock Outlet Diameter

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	1235.678	4	308.9194	6.938984	0.001942	3.006917
Columns	1334.814	4	333.7034	7.495685	0.001336	3.006917
Error	712.3104	16	44.5194			
Total	3282.802	24				

IV. CONCLUSION

The main conclusions of this study are:

(i) The system with 0.55 hub to blade ratio and 20 mm penstock outlet diameter yielded the maximum alternator shaft speed which translates to the highest computed power;
(ii) The results also suggested a minimum departure of the measured alternator shaft speed from the ideal value indicating potentials for minimal loss when the 25 mm penstock outlet for all the hub to blade ratios; and
(iii) The system performance indicates that the optimum hub to blade ratio for this system is in the region of 0.55 as reported in available literature on turbine performance generally.

These will contribute immensely as the system is further developed to attain end user status. Further aspects for investigation will involve attention on the water recycling circuit with a strong case for hybridization with solar energy in order to improve on the mode of power provision for the pump. The pump as turbine option will be investigated.

REFERENCES

[1]. British Petroleum, BP Energy Outlook 2017 Edition, 2017, 9-22, 74-77, 90-94. Available at www.bp.com/energyoutlook#BPstats
[2]. Science for Environment Policy (SEP), Relationships between energy consumption and economic growth investigated, European Commission DG Environment News Alert Service, edited by SCU, The University of the West of England, Bristol, 2013.
[3]. Economic Consulting Associates (ECA), Correlation and causation between energy development and economic growth, 2014, 1-18. Available at https://assets.publishing.service.gov.uk/media/57a089bae5274a27b2000229/EoD_HD116_Jan2014_Energy_Economic_ Growth.pdf
[4]. A.O. Edeoja, J.S. Ibrahim, and E.I. Kucha,Suitability of Pico-Hydropower Technology for Addressing the Nigerian Energy Crisis – A review, International Journal of Engineering Inventions,4(9), 2015a, 17-40.
[5]. S. Lajqi, N. Lajqi, and B. Hamidi, (2016). Design and Construction of Mini Hydropower Plant with Propeller Turbine, International Journal of Contemporary Energy, 2(1), 2016, 1-13.
[6]. W. Xuhe, Z. Baoshan, T. Lei, Z. Jie, and C. Shuliang, Development of a pump-turbine runner based on multi-objective optimization, 27th IAHR Symposium on Hydraulic Machinery and Systems, IOP Conf. Series: Earth and Environmental Science 22, 2014.
[7]. World Energy Council, World Energy Resources - 2013 Survey, 2013, 15, 18, 19, Regency House, 1-4 Warwick Street, London W1B 5LT
[8]. N. Edomah, On the path to sustainability: Key issues on Nigeria's sustainable energy development, Energy Reports, 2, 2016, 28-34.
[9]. G. Omprasad, Power Sector Components, Development, and Reforms: An Overview, International Journal of Development Research, 06(06), 2016, 8156-8163.
[10]. H. Gujba, Y. Mulugetta, and A. Azapagic, The Household Cooking Sector in Nigeria: Environmental and Economic Sustainability Assessment, Resources, 4, 2015, 412-433.
[11]. CPPA, Towards Achieving Sustainable Development for all: Prioritizing Targets for Implementation: Which way forward for Nigeria? 2015. Available from: www.cpparesearch.org/wp-content/.../Country-profile-on-SDGs-Nigeria-Final-Version.pdf
[12]. A.A. Nimje, and G. Dhanjode, Pico-Hydro-Plant for Small Scale Power Generation in Remote Villages, IOSR Journal of Environmental Science, Toxicology and Food Technology, 9(1: III), 2015, 59-67.
[13]. O.S. Oyedepo, Efficient Energy Utilization as a Tool for Sustainable Development in Nigeria, International Journal of Energy and Environmental Engineering, 3, 2012, 11.
[14]. Oluoti, G. Megwai, A. Pettersson, and T. Richards, Nigerian Wood Waste: A Dependable and Renewable Fuel Option for Power Production, World Journal of Engineering and Technology, 2, 2014, 234-248.
[15]. S.C.E. Jupe, A. Michiorri, and P.C. Taylor, Increasing the energy yield of generation from new and sustainable energy sources, Sustainable Energy 14(2), 2007, 37-62.
[16]. E. Bergasse, W. Paczynski, M. Dabrowski, and L. Dewulf, The Relationship between Energy and Socio-Economic Development in the Southern and Eastern Mediterranean, MEDPRO Technical Report No. 27/February 2013. Available from: https://www.ceps.eu/system/files/MEDPRO%20TR27CASE%20Bergasse%20Energy%20and%20Socio-economic%20Development updated15 Feb2013.pdf

[17]. M. Saatci, and Y. Dumrul, The Relationship between Energy Consumption and Economic Growth: Evidence from a Structural Break Analysis for Turkey, International Journal of Energy Economics and Policy 3(1), 2013, 20-29

[18]. A. Pirlogea, and C. Cicea, Econometric perspective of the energy consumption and economic growth relation in European Union, Renewable and Sustainable Energy Reviews, 16, 2012, 5718–5726.

[19]. K. Kamil, Energy Policy and Climate Change in Turkey, Energy Conversion and Management, 44, 2003, 1671-1688.

[20]. A.S. Sambo, Overview of Policy Landscape in Africa on SHP Project Development and Management, Paper presented at International Hydropower Conference, Abuja, 2008.

[21]. Arto, I. Capellán-Pérez, R. Lago, G. Bueno, and R. Bermejo, The energyrequirements of a developed world, Energy for Sustainable Development, 33, 2016, 1-13.

[22]. M.M. Othman, A.J. Razak, M. Basar, N. Muhammad, W. Wan Mohammad, and K. Sopian, A Review of the Pico-Hydro Turbine: Studies on the Propeller Hydro Type, International Review of Mechanical Engineering (IREME), 9 (6), 2015, 527-535.

[23]. MDGs, Nigeria 2015 – Millennium Development Goals End point Report, 2015. Available from: www.mdgs.gov.ng

[24]. International Energy Agency (IEA), World Energy Outlook, 2015. Available online at www.iea.org/t&c/, 1 – 12.

[25]. WHO, Health in 2015: From Millenium Development Goals (MDGs) to Sustainable Development Goals (SDGs), 2015, 3-11.

[26]. N. Lior, Sustainable Energy and Development: The present (2009) Situation and Possible path for the future, Energy, 35, 2010, 3976-3994.

[27]. British Petroleum, BP Energy Outlook 2016 Edition: Outlook to 2035, 2016, 44, 74-77, 90-94. Available at www.bp.com/energyoutlook#BPstats

[28]. U.N. Ekpo, C.A. Chuku, and E.L. Effiong,The Dynamics of Electricity Demand and Consumption in Nigeria: Application of the Bounds Testing Approach, Current Research Journal of Economic Theory, 3(2), 2011, 43-52, 2011.

[29]. UNIDO, UNIDO Projects for the Promotion of Small Hydro Power for Productive Use, UNIDO Evaluation Group, Independent Thematic Review, 2010, 20-39.

[30]. A.S. Sambo, The Role of Energy in Achieving Millenium Development Goals (MDGs), Keynote Address at the National Engineering Technology Conference (NETec 2008), Ahmadu Bello University, Zaria, 1st April, 2008.

[31]. International Energy Agency (IEA), World Energy Outlook 2007 Edition, Available online at www.iea.org/t&c/

[32]. U.B. Akuru, and O.I. Okoro, A Prediction on Nigeria's Oil Depletion Based on Hubbert's Model and the Need for Renewable Energy, ISRN Renewable Energy, 2011.

[33]. A.C. Okoli, and S. Orinya, Oil pipeline vandalism and Nigeria's security, GJHSS, 13, 2013, 67-75.

[34]. J. Williams, and A.F. Alhaji, Parallel with Energy crisis underscore us vulnerability to oil supply shocks today? Oil and Gas Journal, 5, 2003, 101-103.

[35]. N. Onoja, Nigeria losses $11bn to oil theft, vandalism-NEITI, 2013. Available at: http://www.vanguardngr.com/2013/07/nigeria-losses-11bn-to-oil-theft-vandalism-neiti/(retrieved

[36]. EEA, Energy and environment report EEA report no6/2008, European Environmental Agency, 2008.

[37]. M.M. Samy, Techno-Economic Analysis of Hybrid Renewable Energy Systems for Electrification of Rustic Area in Egypt, Innovative Systems Design and Engineering, 8(1), 2017, 42-54.

[38]. A.O. Obande, B.O. Abikoye, P.E. Amiolemhen, The Use of Brewer's Spent Grain as an Effective Energy-Mix Strategy, International Journal of Engineering and Technology, 7(4), 2017.

[39]. U.S. Kumar, and S.Vijayarajan, Feasibility Study of Optimization in Renewable Energy Penetration to an Isolated Hybrid Power Plant, International Journal of Trend in Research and Development, 4(4), 2017, 38-46.

[40]. REN21, Renewables 2016 Global Status Report, 2016. Paris: REN21 Secretariat. Available at: www.ren21.net

[41]. E.I. Ohiman,Diversification of Nigerian Electricity Generation Sources, Energy Sources, Part B: Economics, Planning and Policy, 10(3), 2015, 298-305.

[42]. RETScreen, Clean Energy Project Analysis: RET Screen Engineering & Cases Textbook, 2012. Available at: http://www.retscreen.net/ ang/home.php

[43]. O.O. Ajayi, R.O. Fagbenle, J. Katende, J.M. Ndambuki, D.O. Omole, and A.A. Badejo, Wind Energy Study and Energy Cost of Wind Electricity Generation in Nigeria: Past and Recent Results and a Case Study for South West Nigeria, Energies, 7, 2014, 8508-8534.

[44]. E.J. Bala, Renewable Energy and Energy Efficiency Development in Nigeria, Keynote Paper at the 2-day Workshop on Renewable Energy and Energy Efficiency,10th– 11th June, 2013, NnamdiAzikiwe University, Awka.

[45]. E.J. Bala, Achieving Renewable Energy Potential in Africa, Joint WEC, AUC and APUA Workshop, Addis Ababa, Ethiopia, 17th – 18th June, 2013.

[46]. A.S. Sambo, Strategic Development in Renewable Energy in Nigeria, International Association of Energy Economics, 4, 2009a, 15-19.

[47]. A.S. Sambo, Prospect of Coal for Power Generation in Nigeria, International Workshop on Promotion of Coal for Power Generation, Enugu, 27th-28th April 2009.

[48]. WAEA, Hydropower Resource Assessment, Ministerial Conference on Water for Agriculture and Energy in Africa: The Challenges of Climate Change. Sirte, Libiyan Arab Jamahiriya. December 2008, 15-17.

[49]. W.F. Gary, and D.M. Linkeb, Hydropower as a Renewable and Sustainable Energy Resources Meeting Global Energy Resources in a Reasonable Way, Energy Policy,30, 2002, 1216-1265.

[50]. P.A. Otubu, F.I. Anyasi, and C.E. Ojieabu, Renewable Energy for Generation of Hydro Electric Power to Enhance Rural Telephony and other Infrastructure, International Journal of Electric and Power Engineering, 2(4), 2008, 219 – 224.

[51]. H.M. Ramos, M. Simão, and K.N. Kenov, Low-Head Energy Conversion: A Conceptual Design and Laboratory Investigation of a Microtubular Hydro Propeller, International Scholarly Research Network (ISRN), Mechanical Engineering, 2012, 1 – 10.

[52]. N. Kaseke, and S. G. Hosking, Sub-Saharan Africa Electricity Supply Inadequacy: Implications, Eastern Africa Social Science Research Review, 29(2), 2013, 113-132.

[53]. S. Derakhshan, and N. Kasaeian, Optimal design of axial hydro turbine for micro hydropower plants, 26th IAHR Symposium on Hydraulic Machinery and Systems, IOP Conf. Series: Earth and Environmental Science, 15, 2012.

[54]. V.H. Nguyen, S. Topno, C. Balingbing, V.C.N. Nguyen, M. Röder, J. Quilty, C. Jamieson, P. Thornley, and M. Gummert, Generating a positive energy balance from using rice straw for anaerobic digestion, Energy Reports, 2, 2016, 117–122.

[55]. Yuksel, Renewable Energy Status of Electricity Generation for Future Prospect, Renewable Energy, 50, 2013, 1037-1043.

[56]. E.B. Udah, Openness, Resilience and Economic Growth in Nigeria: An Empirical Investigation, European Journal of Social Sciences, 26(4), 2011, 545-560.

[57]. A.S. Sambo, Matching Electricity Supply with Demand in Nigeria, International Association for Energy Economics, 4th quarter, 2008, 32-36.

[58]. A.S. Sambo, Renewable Energy for rural Development: The Nigerian Perspective, ISESCO Science and Technology Vision, 1, 2005, 12 – 22.

[59]. M. Elbaradai, Addressing the Global Energy Crisis-Managing the Effect of High Energy and Food Price,The Common Wealth Finance Ministers Meeting. St Lucia. 6-8 October, 2008, 1-4.

[60]. World Bank, Technical and Economic Assessment of Off-Grid, Mini-Grid and Grid Electrification Technologies – Summary Report, World Bank Energy Unit; September 2006.

[61]. Omede, and A.A. Omede, Poor and Inadequate Electrical Power Generation, Transmission and Distribution in Nigeria: Economic, Psycho-Social, Health, Security and Educational Consequences, Journal of Applied Science, 1(7), 2015, International Journal of Research and Development Organization.

[62]. D.D. Ajayi, Petroleum, Solid Minerals, Industrial and Power Sectors. In: Nigeria Handbook: All You Need to Know About Nigeria, Published by the Federal Ministry of Information and Communication, Abuja, Nigeria, Chapter 11, 2011, 95-102.

[63]. C.E. Akujor, O.A. Ogungbenro, I.M. Mejeha, O. Nwofor, and G.A. Alozie, The State of Energy Supply in Nigeria: Need for More Efficient Utilization of Fuelwood Resources, Advances in Science and Technology, African Journal for Research, Innovation and Discovery, 5(1S), 2011, 1-4.

[64]. C.A. Madu, A.C. Nwachukwu, and C.E. Akujor, Domestic Energy Preferences for Some Selected Urban Areas of Owerri, South-East, Nigeria, Advances in Science and Technology, African Journal for Research, Innovation and Discovery, 10(1&2), 2016, 12-15.

[65]. I.A. Adejumobi, O.I. Adebisi, and S.A. Oyejide, Developing Small Hydropower Potentials for Rural Electrification, IJRRAS, 17(1), 2013, 105 – 110.

[66]. R. Okeke, 100 million Nigerians are without electricity, The Guardian (Nigeria), 2011. Available at: http://www.ngrguardiannews.com/index.php? option=comcontent&view=article &id=44789:100

[67]. M.O. Oseni, Households' Access to Electricity and Energy Consumption Pattern in Nigeria, Renewable and Sustainable Energy Reviews, 16, 2012, 990–995.

[68]. H. Gujba, Y. Mulugetta, and A. Azapagic, Power generation scenarios for Nigeria: An environmental and cost assessment, Energy Policy, 39, 2011, 968–980.

[69]. H. Gujba, Y. Mulugetta, and A. Azapagic, Environmental and economic appraisal of power generation capacity expansion plan in Nigeria, Energy Policy, 38, 2010, 5636–5652.

[70]. F.A. Sowumi, A.D. Odedeji, and V.O. Akinsoye, Global food and Energy crisis: The need for sustainable food security and Energy program in Nigeria" Current Research Journal for Social Science 1(1), 2009, 15-23.

[71]. A. Awosope, Nigeria Electricity Industry: Issues, Challenges and Solutions, Covenant University 38th Public Lecture, Public Lecture Series. 3(2), 2014. Available at www.covenantuniversity.edu.ng/content/download/35621/.../1/.../38th+Public+Lecture.pdf

[72]. CREN, Nigeria Electricity Crunch, Council for Renewable Energy, Nigeria, 2009. Available at www.renewablenigeria.org

[73]. T.C. Chineke, and E.C. Igwiro, Urban and rural electrification: enhancing the energy sector in Nigeria using photovoltaic technology, African Journal Science and Tech, 9(1), 2008,102–108

[74]. S.O. Igbinovia, and P.E. Orukpe, Rural Electrification: The propelling force for Rural Development of Edo State, Nigeria, Journal of Energy in Southern Africa, 18(3), 2007, 18-26.

[75]. A. Aliyu, A. Ramli, and M. Saleh, Nigeria electricity crisis: Power generation capacity expansion and environmental ramifications, Energy, 61(8), 2013, 354-367.

[76]. S.M. Mustonen, Rural Energy Survey and Scenario Analysis of Village Energy Consumption: A Case Study in Lao People's Democratic Republic, Energy Policy, 38, 2010, 1040 –1048.

[77]. Ikeme, and O.J. Ebohon, Nigeria's Electric Power Sector Reform: What should for the key objectives? Energy Policy, 33, 2005, 1213-1221.

[78]. F.I. Ibitoye, and A. Adenikinju, Future Demand for Electricity in Nigeria, Applied Energy, 84, 2007, 492-504.

[79]. F.I. Ibitoye, The millennium development goals and household energy requirements in Nigeria, Springer Plus, 2, 2013, 529

[80]. E.A. Ajani, O.A. Olasupo, O.I. Oyelade, S.O.O. Olusunle, and O.O. Adewoye, Developing Local Manufacturing Capacity for SHP Equipment: NASENI Experience, Advances in Science and Technology, African Journal for Research, Innovation and Discovery, 5(1S), 2011, 5-16.

[81]. Adamkowski, Discharge Measurement Techniques in Hydropower Systems with Emphasis on the Pressure-Time Method, Hydropower - Practice and Application, Dr. Hossein Samadi-Boroujeni (Ed.), InTech, 2013. Available from: http://www.intechopen.com/books/ hydropower-practice-andapplication/ some-recent-achievements-in-discharge-measurements

[82]. M.A. Haidar. F.M. Senan, A. Noman, and R. Taha, Utilization of Pico hydro generation in domestic and commercial loads, Renewable and Sustainable energy reviews, 16, 2012, 518-524.

[83]. O.O. Fagbohun, Studies on Small Hydro-Power Potentials of Itapaji Dam in Ekiti State, Nigeria, International Journal of Engineering Science Invention, 5(1), 2016, 28-26.

[84]. B. Ziter, Site Assessment and Design of a Small Off-grid Hydroelectric System at the Jama-Coaque Ecological Reserve in Coastal Ecuador, 2013. Available at http://tmalliance.org/live/wp-content/uploads/2013/11/Late-Summer-2013-Hydroelectric-Final-Report-brett.pdf.

[85]. T. Ajuwape, and O.S. Ismail, Design and Construction of a 5 kW Turbine for a Proposed Micro Hydroelectric Power Plant Installation at Awba Dam University of Ibadan, International Journal of Electrical and Power Engineering, 5(3), 2011, 131– 138.

[86]. S. Mishra, S.K. Singal, and D.K. Khatod, Optimal Installation of Small Hydropower Plant - A review, Renewable and Sustainable Energy Reviews, 15, 2011a, 3862– 3869.

[87]. S. Mishra, S.K. Singal, and D.K. Khatod, Approach for Cost Determination of Electro-Mechanical Equipment in RoR SHP Projects, Smart Grid and Renewable Energy, 2, 2011b, 63 - 67.

[88]. T. Gaius-Obaseki, Hydropower Opportunities in the Water Industry, International Journal of Environmental Sciences, 1(3), 2010, 392-402.

[89]. P. Nikolaisen, 12 Mega dams that changed the world but not necessarily for the better, 2015. Available from: http://www.tu.no/artikler/12-megadammer-som-endret-verden/223528

[90]. M.T. Gatte, and R.A. Kadhim, Hydro Power, In Energy Conservation, Ed. A. Z. Ahmed, InTechJanezaTrdine 9, 51000 Rijeka, Croatia, 2012, 95 – 124.

[91]. G. Gunkel, Hydro Power-A Green Energy Tropical Reservoir and Green House Gas Commissions, Clean Soil, Air, Water,39(9), 2009, 726-734.

[92]. C.S. Kaunda, C.Z. Kimambo, and T.K. Nielsen, Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa, ISRN Renewable Energy, 2012.

[93]. O.S. Ohunakin, S.J. Ojolo, and O.O. Ajayi, Small Hydropower (SHP) Development in Nigeria, Renewable and Sustainable Energy Reviews, 15, 2011, 2006 – 2013.

[94]. H.D. Olusegun, A.S. Adekunle, I.O. Ohijeagbon, O.A. Oladosu, and H.A. Ajimotokan, Retrofitting a Hydropower Turbine for the Generation of Clean Electrical Power, USEP: Journal of Research Information in Civil Engineering, 7(2), 2010, 61-69.

[95]. K. Manohar, and A.A Adeyanju, Hydropower resources in Nigeria, Journal of Engineering and Applied Sciences, 4(1), 2009, 68-73.

[96]. NASENI, Powering the Nation through NASENI's Small Hydro Power, NASENI Watch, 1(2), January 2013, Available at www.naseni.org.

[97]. D.O. Olukanmi, and A.W. Salami, Assessment of Impact of Hydropower Dams Reservoir Outflow on the Downstream River Flood Regime – Nigeria’s Experience, Hydropower – Practice and Application, Dr. Hossein Sammad-Boroujeni (Ed.), 2012. Available from: http://www.intechopen.com/books/hydropower-practice-and-application/assessment-of-impact-of-hydropower-dams-reservoir-overflow-on-the-downstream-river-flood-regime-niger

[98]. Matthews, Water Grabbing in the Mekong Basin – An Analysis of the Winners and Losers of Thailand’s Hydropower Development in Lao PDR, Water Alternatives, 5(2), 2012, 392 – 411.

[99]. E.C. Finardi, and M.R. Scuzziato, Hydro Unit Commitment and Loading Problem for Day-Ahead Operation Planning Problem, Electrical Power and Energy Systems, 44, 2013, 7-16.

[100]. C. Cheng, J. Shen, X. Wu, and K. Chau, Operation Challenges for Fast-Growing China’s Hydropower Systems and Respondence to Energy Saving and Emission Reduction, Renewable and Sustainable Energy Reviews, 16, 2012, 2386 – 2393.

[101]. P. Block, Tailoring Seasonal Climate Forecasts for Hydropower Operations, Hydrology and Earth System Science, 15, 2011, 1355 – 1368.

[102]. P. Block, Tailoring Seasonal Climate Forecasts for Hydropower Operations in Ethiopia’s Upper Blue Nile Basin, Hydrology and Earth System Science Discussions, 7, 2010, 3765–3802.

[103]. Cunbin, L. Xian, and W. Minxia, Risk Analysis Simulation Model of Economic Evaluation in Hydroelectric Engineering Project, Research Journal of Applied Sciences, Engineering and Technology, 4(14), 2012, 2222 – 2226.

[104]. N. Perkins, D. Dixon, and B. Murtha, Better Turbines–For the Economy and Fish Alike, Workshop on Rehabilitation of Hydropower, October 12th and 13th, 2011.

[105]. P. Baumann, and G. Stevanella, Fish Passage Principles to be considered for Medium and Large Dams: The Case Study of a Fish Passage Concept for a Hydroelectric Power Project on the Mekong Mainstream in Laos, Ecological Engineering, 48, 2012, 79–85.

[106]. Z. Deng, T.J. Carlson, D.D. Dauble, and G.R. Ploskey, Fish Passage Assessment of an Advanced Hydropower Turbine and Conventional Turbine Using Blade-Strike Modelling, Energies, 4, 2011, 57 – 67.

[107]. Z.D. Deng, J.J. Martinez, A.H. Colotelo, T.K. Abel, A.P. LeBarge, R.S. Brown, B.D. Pflugrath, R.P. Mueller, T.J. Carlson, A.G. Seaburg, R.L. Johnson, and M.L. Ahmann, Development of External and Neutrally Buoyant Acoustic Transmitters for Juvenile Salmon Turbine Passage Evaluation, Fisheries Research, 113, 2012, 94-105.

[108]. J.J.L.S. da Silva, M. Marques, and J.M. Damásio, Impacts on Tocantins River Aquatic Ecosystems Resulting from the Development of the Hydropower Potential, AmbienteeÁgua, An Interdisciplinary Journal of Applied Science, 5(1), 2010, 189-203.

[109]. Ayer, Let’s Adopt a More Balanced View on the Role of Existing Hydropower in Renewable Portfolio Standards, A Publication of Elsevier, 21(8), 2008.

[110]. H.I. Jager, and B.T. Smith, Sustainable Reservoir Operation: Can We Generate Hydropower and Preserve Ecosystem Values? River Research and Application, 24, 2008, 340 – 352.

[111]. E.P. Anderson, M.C. Freeman, and C.M. Pringle, Ecological Consequences of Hydropower Development in Central America: Impacts of Small Dams and Water Diversion on Neotropical Stream Fish Assemblages, River Research and Application, 22, 2006a, 397- 411.

[112]. V. Chanudet, S. Descloux, A. Harby, H. Sundt, B.H. Hansen, O. Brakstad, D. Serça, and F. Guerin, Gross CO_2 and CH_4 Emissions from the Nam Ngum and Nam Leuk Sub-Tropical Reservoirs in Lao PDR, Science of the Total Environment, 409, 2012, 5382 – 5391.

[113]. K. Hussey, and J. Pittock, The Energy–Water Nexus: Managing the Links between Energy and Water for a Sustainable Future, Ecology and Society, 17(1), 2012, 31 – 39.

[114]. C. Bohlen, and L.Y. Lewis, Examining the Economic Impacts of Hydropower Dams on Property Values using GIS, Journal of Environmental Management, 90, 2009, S258 – S269.

[115]. E.P. Anderson, C.M. Pringle, and M.C. Freeman, Quantifying the Extent of River Fragmentation by Hydropower Dams in the Sarapiquí River Basin, Costa Rica, Aquatic Conservation: Marine Freshwater Ecosystem, 16, 2008, 406 – 417.

[116]. E.P. Anderson, C.M. Pringle, and M. Rojas, Transforming Tropical Rivers: An Environmental Perspective on Hydropower Development in Costa Rica, Aquatic Conservation: Marine Freshwater Ecosystem, 16, 2006b, 679–693.

[117]. M.B. Amor, P. Pineau, C. Gaudreault, and R. Samson, Electricity Trade and GHG Emissions : Assessment of Quebec's Hydropower in the North-eastern American Market (2006 – 2008), Energy Policy, 39, 2011, 1711 – 1721.

[118]. L. Liu, H. Chen, X. Yuan, Z. Chen, and Y. Wu, Unexpected CH_4 Emission from the Three Gorges Reservoir and its Implications, ActaEcologicaSinica, 31(5), 2011, 233 – 234.

[119]. V.B. Miller, A.F. Landis, and L.A. Schaefer, A Benchmark for Life Cycle Air Emissions and Life Cycle Impact Assessment of Hydrokinetic Energy Extraction using Life Cycle Assessment, Renewable Energy, 36, 2011, 1040 - 1046.

[120]. Horlacher, T. Heyer, C.M. Ramos, and M.C. da Silva, Management of Hydropower Impacts through Construction and Operation, Comprehensive Renewable Energy, 6, 2012, 49 - 91.

[121]. Y. Yassi, and S. Hasemloo, Improvement of the Efficiency of a New Micro Hydro Turbine at Part Loads due to Installing Guide Vane Mechanism, Energy Conversion And Management, 51(10), 2010, 1970-1975.

[122]. A. Von Flotow, Micro Hydro Penstock Design, Oregon State University Independent Study and Research Fellow Transcript Notation, June 2, 2012

[123]. A. Pascale, T. Urmee, and A. Moore, Life cycle assessment of a community hydroelectric system in rural Thailand, Renewable Energy, 36(11), 2011, 2799-2808.

[124]. K.V. Alexander, E.P. Giddens, and A.M. Fuller, Axial-flow turbines for low head micro hydro systems, Renewable Energy, 34, 2009a, 35 – 47.

[125]. K.V. Alexander, E.P. Giddens, and A.M. Fuller, Radial- and mixed-flow turbines for low head micro hydro systems, Renewable Energy, 34(7), 2009b, 1885 - 1894.

[126]. P. Maher, N.P.A. Smith, and A.A. Williams, Assessment of Pico hydro as an option for off-grid electrification in Kenya, Renewable Energy, 28, 2003, 1357 – 1369.

[127]. B.R. Cobb, and K.V. Sharp, Impulse Turbine Performance Characteristics and Their Impact on Pico-Hydro Installation, Renewable Energy, 50, 2013, 959-964.

[128]. M. Wohlgemuth, Assessment of pico-hydro power potential in rural Ethiopia, Bachelor of Science Thesis submitted to the Department for Hydrology and River Basin Management, TechnischeUniversitätMünchen

[129]. L. Wang, A Micro Hydro Power Generation System for Sustainable Micro Grid Development in Rural Electrification in Africa, IEE Power Energy Society Meeting, Calgary Canada. 2009, 1-8.

[130]. A. Chhetri, G.R. Pokharel, and M.R. Islam, Sustainability of micro hydro systems- A case study, Energy and environment,20(4), 2009, 567-585.

[131]. K.V. Alexander, and E.P. Giddens, Optimum Penstocks for Low Head Micro hydro Schemes, Renewable Energy, 33, 2008a, 507 –519.

[132]. K.V. Alexander, and E.P. Giddens, Micro hydro: Cost-effective, modular systems for low heads, Renewable Energy, 33, 2008b, 1379 –1391.

[133]. B.R. Cobb, Experimental Study of Impulse Turbines and Permanent Magnet Alternators for Pico-hydropower Generation, Master degree thesis, Department of Mechanical Engineering, Oregon State University, 2011.

[134]. P. Maher, Kenya Case Study 1 at Kathamba and Case Study 2 at Thima, 2002a. Available from: http://www.eee.nottingham.ac.uk/picohydro/documents.html#kenya

[135]. P. Maher, Design and implementation of a 2.2 kW pico hydro serving 110 households, Micro Hydro Centre – Nottingham Trent University, 2002b. Available from: http://www.eee.nottingham.ac.uk/picohydro/ documents. html

[136]. P. Maher, and N. Smith, Pico hydro for village power – a practical manual for schemes up to 5W in hilly areas. Micro Hydro Centre – Nottingham Trent University, 2001. Available from: http://www.eee.nottingham.ac.uk/picohydro/documents.html

[137]. N. Smith, and A. Williams, Assessment of Pico Hydro as an Option for Off Grid Electrification in Kenya, Micro Hydro Centre Nottingham Trent University, 2003, 1357-13569.

[138]. A.O. Edeoja, and L. Awuniji, Experimental Investigation of the Influence of Penstock Configuration and Angle of Twist of Flat Blades on the Performance of a Simplified Pico-Hydro System, EJERS, European Journal of Engineering Research and Science, 2(7), 2017, 14-22.

[139]. D.T. Ipilakyaa, A.O. Edeoja, and A. Kulugh, Influence of Penstock Outlet Diameter and Flat Blade Lateral Twist Angle on the Performance of a Simplified Pico Hydropower System, International Journal of Trend in Scientific Research and Development (IJTSRD), 1(5), 2017, 394-406.

[140]. A.O. Edeoja, J.S. Ibrahim, and E.I. Kucha, Investigation of the Effect of Penstock Configuration on the Performance of a Simplified Pico-hydro System, British Journal of Applied Science & Technology, 14(5), 2016a, 1-11.

[141]. A.O. Edeoja, J.S. Ibrahim, and L.T. Tuleun, Effect of Blade Cross-Section on the Performance of a Simplified Pico-Hydro System, American Journal of Engineering Research (AJER), 5(12), 2016b, 1 – 9.

[142]. A.O. Edeoja, J.A. Edeoja, and M.E. Ogboji, Effect of Number of Turbine Runner V-Blades on the Performance of a Simple Pico-Hydro System, Accepted for publication in International Journal of Engineering and Technology, Reference number 316145147726833, 2016c.

[143]. A.O. Edeoja, J.S. Ibrahim, and E.I. Kucha, Conceptual Design of a Simplified Decentralized Pico Hydropower with Provision for Recycling Water, Journal of Multidisciplinary Engineering Science and Technology (JMEST), 2(2), 2015b.

[144]. J.H. Park, N.J. Lee, J.V. Wata, Y.C. Hwang, Y.T. Kim, and Y.H. Lee, Analysis of a Pico hydro turbine performance by runner blade shape using CFD, 26th IAHR Symposium on Hydraulic Machinery and Systems IOP Publishing IOP Conf. Series: Earth and Environmental Science 15, 2012.

[145]. S. Sangal, G. Arpit, and K. Dinesh, Review of Optimal Selection of Turbines for Hydroelectric Projects, International Journal of Emerging Technology and Advance Engineering, 3, 2913, 424-430.

[146]. M.M. Alnakhlani, D.A. Mukhtar, A. Himawanto, A. Alkurtehi, and D. Danardono, Effect of the Bucket and Nozzle Dimension on the Performance of a Pelton Water Turbine, Modern Applied Science, 9(1), 2015, 25-33.

[147]. M.F. Basar, and M. Masjuri, Overview of the Key Components of a Pico Hydro Power Generation System, Latest Trend in Renewable Energy and Environment Informatics, 2013. Available at http://www.ufem.ed.my.

[148]. A. Williams, Pico Hydro for Cost Effective Lighting, Boiling Point Magazine, May 2007, 14-16.

[149]. N. Smith, and S.R. Bush, A Light Left in the Dark: The Practice and Politics of Pico Hydro Power in the Laos PDR, Energy Policy, 38(1), 2010, 116-127.

[150]. S. Kamaruzzaman, and A.B. Juhari, Pico Hydro: Clean Power from Small Streams, Proceeding of the 3rd WSEAS. International Conference on Renewable Energy Sources, 2009, 414-419.

[151]. R. Hothersal, Hydro Dynamic Design Guide for Small Francis and Propeller Turbines Vienna, Austria, 2004, United Nations Industrial Development Organization.

[152]. D.A. Harvey, Axial Flux Permanent Magnet Generators for Pico Hydro Power, Enb-Uk Research Conference, 2009, The Royal Academy Of Engineering.

[153]. Ho-yan, Tela turbine for Pico hydro applications, Guelph Engineering Journal, 4, 2011, 1-8.

[154]. Ho-Yan, Design of a Low Head Pico Hydro Turbine for Rural Electrification in Cameroon, Thesis presented to The University of Guelph, Canada, 2012. Retrieved from https://dspace.lib.uoguelph.ca/xmlui/handle/10214/3552

[155]. R. Balaka, A. Rachman, and J. Delly, Blade Number Effect for A Horizontal Axis River Current Turbine at A Low Velocity Condition Utilizing A Parametric Study with Mathematical Model of Blade Element Momentum, Journal of Clean Energy Technologies, 2(1), 2014, 1-5.

[156]. H. Zanuddin, M.S. Yahaya, J.M. Laze, M.F. 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, 59, 2009, 155-159.

[157]. B. Ho-Yan, and W.D. Lubitz, Performance evaluation of cross-flow turbine for low head application, Proc. of World Renewable Energy Congress, Linköping, Sweden. May 8-11, 2011.

[158]. B. Ho-Yan, W.D. Lubitz, C. Ehlers, and J. Hertlein, Field Investigation in Cameroon towards a more appropriate Design of a Renewable Energy Pico Hydro system for Rural electrification,. Tech4Dev Intl. Conference. EPFL, Lausanne, Switzerland. May 29-31, 2012.

[159]. M.J. Muchira, Performance of a Modified Vehicle Drive System in Generating Hydropower, Master of Science Thesis, Kenyatta University, Nairobi, Kenya, 2011.

[160]. A. Kunwor, Technical Specifications of Micro Hydro Systems Design and its Implementation: Feasibility Analysis and Design of LamayaKhola Micro Hydro Power Plant, Bachelor Degree Thesis, Arcada Polytechnic, Helsinki, Finland, 2012.

[161]. P. Adhikari, U. Budhathoki, S.R. Timilsina, S. Manandhar, and T.R. Bajracharya, A Study on Developing Pico Propeller Turbine for Low Head Micro Hydropower Plants in Nepal, Journal of the Institute of Engineering, 9(1), 2013, 36–53.

[162]. W. Nuantong, and S. Taechajedcadarungsri, Flow Simulations on Blades of Hydro Turbine, International Journal of Renewable Energy, 4(2), 2009.

[163]. D. Singh, Micro Hydro Power Resource Assessment Handbook, Asian and Pacific Centre for Transfer of Technology of the United Nations – Economic and Social Commission for Asia and the Pacific (ESCAP), 2009, 1-29

[164]. T. Sanchez, and L. Rodriguez, Designing and Building Mini and Micro Hydro Power Schemes: A Practical Guide. Practical Action, June 2011.

[165]. S. Paudel, N. Linton, U.C.E. Zanke, and N. Saenger, Experimental investigation on the effect of channel width on flexible rubber blade water wheel performance, Renewable Energy, 52, 2013, 1-7

[166]. S.J. Williamson, B.H. Stark, J.D. Booker, Low Head Pico Hydro Turbine Selection using a Multi-Criteria Analysis, World Renewable Energy Congress: Hydropower Applications, 8-13 May, 2011, 1377-1385.

[167]. M.B. Farriz, H. Boejang, M. Masjuri, M.S.M. Aras, N.H.A. Razik, S. Mat, and K. Sopian, Evolution of Simple Reaction Type Turbines for Pico-Hydro Applications, JurnalTeknologi, 77(32), 2015. 1–9.

[168]. B.J. Lewis, J.M. Cimbala, and A.M. Wouden, Analysis and Optimization of Guide Vane Jets to Decrease the Unsteady Load on Mixed Flow Hydroturbine Runner Blades, 7th International Conference on Computational Fluid Dynamics (ICCFD7), Big Island, Hawaii, July 9-13, 2012, 1-12.

[169]. S. Yadav, Some Aspects of Performance Improvement of Pelton Wheel Turbine with Reengineered Blade and Auxiliary Attachments, International Journal of Scientific & Engineering Research, 2(9), 2011. http://www.ijser.org

[170]. G. Pengcheng, L. Xingqi, L. Weili, Z. Xiaobo, and L. Peng, Effect of blade geometric parameters on the operating stability of the hydraulic turbine, Proceedings of the 4th WSEAS International Conference on Fluid Mechanics and Aerodynamics, Elounda, Greece, August 21-23, 2006, 315-318

[171]. A. Arslan, R. Khalid, Z. Hassan, and I. A. Manarvi, Design and Manufacture of a Micro Zero Head Turbine for Power Generation, International Journal of Multidisciplinary Sciences and Engineering, 2(7), 2011, 35-38.

[172]. M.A. Khan, and S. Badshah, Design and Analysis of Cross Flow Turbine for Micro Hydro Power Application using Sewerage Water, Research Journal of Applied Sciences, Engineering and Technology 8(7), 2014, 821-828

[173]. Ayancik, U. Aradag, E. Ozkaya, K. Celebioglu, O. Unver, and S. Aradag, Hydroturbine Runner Design and Manufacturing, International Journal of Materials, Mechanics and Manufacturing, 1(2), 2013, 162-165.

[174]. J.L. Chukwuneke, C.H. Achebe, P.C. Okolie, and H.A. Okwudibe, Experimental Investigation on the Effect of Head and Bucket Splitter Angle on the Power Output of a Pelton Turbine, Journal of Information Engineering and Applications, 4(10), 2014.