Jurnal Teknologi

Full Paper

REVIEW ON THE POTENTIAL OF MICRO HYDRO ELECTRIC GENERATOR EMBEDDED AT EFFLUENT DISCHARGE OF SEWERAGE TREATMENT PLANT

Article history
Received
11 July 2015
Received in revised form
15 November 2015
Accepted
27 November 2015

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Graphical abstract

Abstract

A micro hydroelectric generator is an energy conversion approach to generate electricity from potential (motion) energy to an electrical energy. It is desired to be implemented by using a micro-hydro electric generator which is embedded at the continuous flow of effluent discharge point of sewerage treatment plant (STP). Any conventional STP is appropriate with domestic wastewater and an effective and approved technology to control water discharged according to local requirements which at the same time suitable to drive a turbine rotation head of a dynamo. This paper evaluate the potential of electricity generation using micro-hydro generator turbine attached to a selective sizing of an electrical dynamo and system regulator to produce electrical energy which meets the minimum power quality for domestic use. The overview of micro hydro electric generator on the actual application and suggestion made by previous researchers is summarized.

Keywords: Micro hydro generator, sewerage treatment plant, off grid generator

Abstrak

Penjana hidro mikro merupakan pendekatan penukaran tenaga untuk menjana elektrik daripada tenaga keupayaan (pergerakan) kepada tenaga elektrik. Ia diharap untuk dilaksanakan melalui pemasangan satu penjana elektrik mikro pada punca keluar air effluen yang berterusan di logi rawatan kumbahan. Logi rawatan kumbahan berkenaan adalah logi perawatan air sisa yang biasa dengan pengeluaran air dalam kualiti dan standard yang diluluskan mengikut peraturan tempatan dan dalam masa sama bersesuaian untuk memacu putaran turbin pada kepala sesebuah dinamo. Kajian ini menilai potensi penjanaan elektrik menggunakan turbin penjana hidro mikro terpasang pada saiz tertentu dinamo elektrik dan sistem pengatur untuk menghasilkan tenaga elektrik yang menepati kualiti sistem kuasa bagi penggunaan domestik. Sorotan penjana elektrik hidro mikro dari aspek penggunaan dan cadangan penyelidik terdahulu akan dirumuskan.

Kata kunci: Penjana hidro mikro, logi rawatan kumbahan, penjana luar-grid

1.0 INTRODUCTION

Energy issue has become a national problem and has gathered attention from the government of Malaysia. The government is now enforcing an Electric Supply Act 1990 [1] whereby it comprises another subchapter from the act on Rules of Managing Electrical Energy Efficiently 2008 [2].

In 2009, the government established the Ministry of Energy, Green Technology and Water to enforce and support the nation's developments more towards sustainability and energy efficiency through Renewable Energy and Energy Efficiency. In 2011, the Sustainable Energy Development Authority of Malaysia (SEDA) [3] was established as a statutory body formed under the Sustainable Energy

Development Authority Act 2011 (Act 726, 2011) [4] with intention to administer and manage the implementation of the feed-in tariff mechanism which is mandated under the Renewable Energy Act 2011 (Act 725) [5]. On top of this the government has also introduced the Green Building Index (GBI) [6] certification in 2009 as a rating system towards energy efficiency for new and existing buildings. These actions suggested government urgency towards energy efficiency nationwide.

In 2014, the Energy Commission summarized that the maximum demand for electricity in Peninsular Malaysia increased about 2% yearly with the current limited generation cropped at 21,817 MW [7]. Of this approximately 300 MW (1.3%) generated from renewable energy and this is far below the targeted value of 25% by the Government [4]. Therefore an isolated solution such as micro hydroelectric power is highly desirable to support the Malaysian Renewable Energy agenda where the application is aimed to be at the discharge point of sewerage treatment plant (STP). The aim of this development is to have a self-ecosystem electrical generation system which embedded at STP since the flowing water from the discharge is also a potential source of energy that possible to be harvest for electrical generation.

A micro hydroelectric power is a conversion system for generating power to drive an electrical system from potential (motion) energy to an electrical energy. It is desired to be implemented by using a small scale micro hydro electric generator which is embedded at the continuous flow of effluent discharge point of STP. Any conventional STP plants with an effective and approved quality of water discharged according to local requirements are suitable for this purpose.

The assessment will be on the application of the micro-hydro generator turbine, attached to a selective sizing of an electrical dynamo and system regulator to produce electrical power which meets the minimum power quality for its own use. The water effluent preparation due to the size, motion, flow rate, head and other minimum criteria to suit the electrical turbine is presented in this paper. On the other hand, the discussion of micro hydro electric generator will be based on the actual application and suggestion made by previous researchers.

2.0 OVERVIEW OF HYDRO ELECTRIC

Fulford *et al*. [8] summarized that the hydro-electric generator category can be simplified in Table 1. The possible micro hydro output power will be 12 kW in size, this is due to the simplicity of the design and the wide application especially in STP. The general power requirement for STP will be based on the Population Equivalent (PE) system and 12 kW is the optimum power for both application and research activities.

Table 1 Classification of hydro system [8]

Size	Application	Power	Classification
Very Small	Family	Less than 5kW	Pico-hydro
Small	Village scale	5kW – 100kW	Micro-Hydro
Medium	Mini Grid	100kW – 5MW	Mini-Hydro
Full Size	Grid connected	Greater than 5MW	Full-scale

Fulford *et al*. [8], Harvey *et al*. [9] and Rijal [10] indicated that a small turbine technology has been developed in many countries that allowed both shaft power and electricity to be generated from small stream flowing, cheaply and efficiently as reported by Joshi and Amatya [11] and Shresta [12] in Uganda, Sri Langka, Nepal and Uthopia. However the projects were using river in their countries in order to have an electrical energy to electrify the rural area.

In Malaysia, the development of mini hydro for commercialization started in 2011 through Fit in Tariff (FiT) encouraged by Sustainable Energy Development Authority of Malaysia (SEDA) [3]. The mini hydro normally built at 2 to 5 MW and aimed for bigger application and tariff driven incentives with grid connected. The micro hydro however having more potential to be used even without FiT incentives but the investment cost need to be minimal. For instance, the solar photovoltaic energy investment was understood to be at approximately RM10,000 per kW [13] and therefore micro hydro also need to be within the range and between 10-20% higher for maintenance purposes. Unlike solar system which depending on sunlight, the strength of having the micro hydro is the continuous flow of effluent discharge which promises continuous energy harvesting.

The implementation of micro hydro electric generator requires consideration of two engineering disciplines, namely environmental and electrical engineering. The integration of these disciplines will able to cultivate and encourage research towards sustainable engineering and safer environment.

2.1 The Environmental Consideration

The Technical Standards and Compliance Division of Sewerage Regulatory Department, National Water Services Comission (SPAN) [14, 15, 19] outlined that the quality of effluent water that need to be monitored in accordance to ISO/IEC 17025 [16] and Water Services Industry Act 2006 [17, 18] as indicated in Table 2:

Table 2 The minimum requirement of effluent's discharge quality [34, 35]

No	Characteristic	Standard A	Standard B
1	Temperature	40°C	40°C
2	BOD at 20°C	20 mg/l	50 mg/l
3	COD	50 mg/l	100 mg/l
4	TSS	50 mg/l	100 mg/l
5	Oil and grease	Not detecable	10 mg/l
6	pH	6.0 – 9.0	5.5 – 9.0
7	Mercury	0.005 mg/l	0.05 mg/l
8	Arsenic	0.05 mg/l	0.1 mg/l
9	Cadmium	0.01 mg/l	0.02 mg/l
10	Lead	0.1 mg/l	0.5 mg/l
11	Sulphide	0.5 mg/l	0.5 mg/l

The test method of these parameters shall be according to Standard Methods for the Examination of Water and Wastewater, published jointly by the American Public Health Association, the American Water Works Association and the Water Environment Federation of the United States of America; or Code of Federal Regulations, Chapter 40, Subchapter D, part 136 published by the Office of the Federal Register, National Archives and Records Administration, United States of America [19].

Despite the unclean of incoming influent water, the micro hydro system which is intended to be embedded at the effluent discharge point shall have the above minimum characteristic of water quality so that the environmental consideration especially in wastewater treatment is fully complied.

Effluent weir also need to comply with the regulation where shall be accessible from top for manual cleaning without causing obstruction and not posing any health and safety issues. The weirs shall always be levelled for even distribution of flow. Slots in the weir shall be provided to allow for level adjustment during the installation stage (Figure 1).

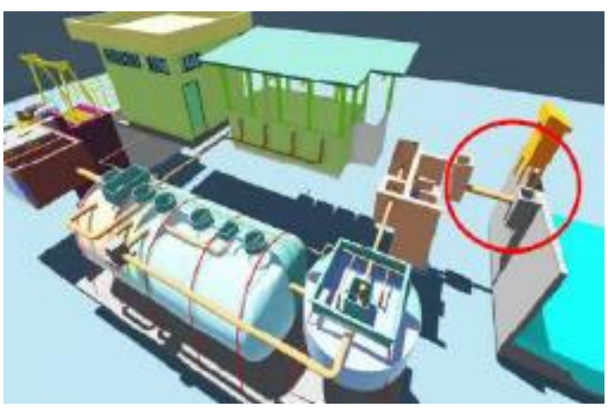

Figure 1 The location of effluent weir and effluent discharge pipe at STP (highlighted in circle)

Flow through over the weir shall be calculated based on the actual type of weir used. Next, the eluent pipe shall passes through the disinfection treatment facility and shall be designed so as not to cause any nuisance. The invert level of effluent pipe shall be at a minimum of 300 mm from the top water level of receiving watercourse (Figure 2) [19].

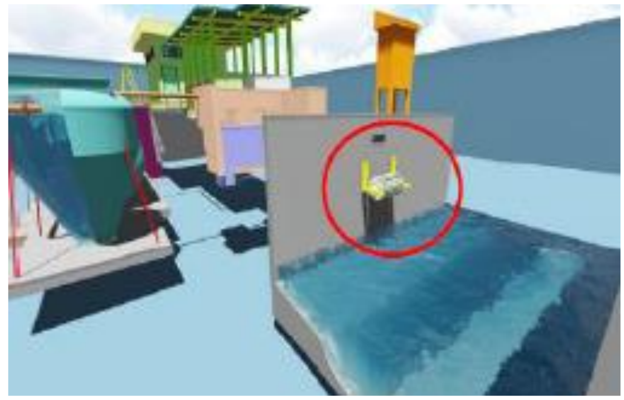

Figure 2 The effluent discharge pipe to be embedded with a micro hydro at STP (highlighted in circle)

These requirements shall be fully comply in order to install and operate the micro hydro electric generator which is intended to minimize the adjustment on the final discharge design with the current regulations related to water quality established by SPAN and Indah Water Konsortium (IWK) [20]. The compliance is important so that the installation of micro hydro into the STP system shall not affect the overall approval.

2.2 The Electrical Consideration

The compliance with the local electrical regulations and characteristic requirements is essential so that the application can meet the minimum electrical power quality desired and to suit with the normal electrical board application. This is important due to stringent electrical regulations related to safety and reliability of electrical power generated to safeguard both human and equipment during operation. Some of the regulations and standard applies is summarised in Table 3.

Table 3 The minimum requirement of electrical regulations and guidelines

No	Regulation/Standard/Act	Level
1	Electricity Supply Act 1990 – Act 447 [1]	Malaysia
2	Licensee Supply Regulation 1990 [21]	Malaysia
3	Electricity Regulation 1994 [22]	Malaysia
4	Occupational, Safety & Health Act 1994 [23]	Malaysia
5	Malaysia Standard MS IEC 60364 Electrical Installation of Buildings [24]	Malaysia/ International
6	IEE Wiring Regulation 16th Edition [25]	International
7	Electricity Supply (Successor Company) Act 1990 [26]	Malaysia

Low-voltage installations are governed by numbers of regulatory and advisory texts, which may be classified as follows:

1) Statutory regulations (decrees, factory acts, etc.)
2) Codes of practice, regulations issued by professional institutions, job specifications.
3) National and international standards for installations and products.

In general the aim of electrical regulations and standard are as follows:

1) Safety - To design the power system which will not present any electrical hazard to the people who utilize the facility, and/or the utilization equipment fed from the electrical system.
2) Minimum Initial Investment - The owner's overall budget for first cost purchase and installation of the electrical distribution system and electrical utilization equipment will be a key factor in determining which of various alternate system designs are to be selected. Consideration should be given to the cost of installation and other requirements.
3) Maximum Service Continuity - The degree of service continuity and reliability needed will vary depending on the type and use of the facility as well as the loads or process being supplied by the electrical distribution system.
4) Maximum Flexibility & Expendability - In many industrial manufacturing plants, electrical utilization loads are periodically relocated or changed requiring changes in the electrical distribution system. Consideration of the layout and design of the electrical distribution system to accommodate these changes must be considered.
5) Maximum Electrical Efficiency (Minimum Operating Costs) - Electrical efficiency can generally be maximized by designing systems that minimize the losses in conductors, transformers and utilization equipment. Proper voltage level and power plays a key factor in this area. Selecting equipment, such as dynamo, with lower operating losses, generally means higher first cost and increased efficiency.
6) Minimum Maintenance Cost - Usually the simpler the electrical system design and equipment, the less the associated maintenance costs and operator errors. As electrical systems and equipment become more complicated to provide greater service continuity or flexibility, the maintenance costs and chance for operator error increases. The systems should be designed with an alternate power circuit to take electrical equipment (requiring periodic maintenance) out of service without dropping essential loads. Use of drawout type protective devices such as breakers and combination starters can also minimize maintenance cost and out-of-service time.
7) Maximum Power Quality - The power input requirements of all utilization equipment has to be considered including the acceptable operating range of the equipment and the electrical distribution system has to be designed to meet these needs.

2.3 Micro Hydro Electric at Effluent STP

Both environmental and electrical consideration is required to materialize the generation and application concept. The flowing of wastewater to the STP shall be normally treated with the consideration and preparation of final effluent discharge to suit the micro hydro requirements.

In general, the water head and water flow rate are the two most important factors that determine the suitability of the micro hydro [33]. Other quantitative and qualitative criteria's [28] shall also consider during implementation as stipulated in Table 4.

Table 4 The criteria in selection of micro-hydro application

Quantitative Criteria	Qualitative Criteria
Rated flow/head efficiency	Environmental-weather-location
Part flow/head efficiency	Required civil works
Cost	Portability
Turbine rotational speed	Maintainability
Power for given site	Reliability
Size of system	Ease of manufacturer, design modularity

Meanwhile, the micro hydro power application for low head as STP can be categorized into 2 types as illustrate in Figure 3.

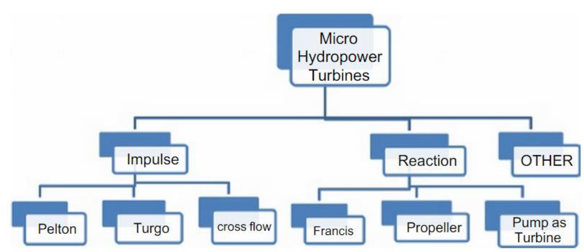

Figure 3 The classification of Micro Hydro [28]

The application of Turgo and Pelton turbine (from Impulse Turbine Category) seems to be more challenging for STP due to their application is generally for high and medium heads [29]. Therefore the use of cross flow or reaction turbines, i.e propeller or Francis turbine is preferable option for STP. This is due to the low head and flow rate of STP which depend to the gravity and final discharge effluent point that is normally designed for its operation [30, 31]. The normal head of STP effluent discharge generally can be set at 1 to 3 meter only, due to the availability of nearest discharge which is normally within that range that needs to be suited for environmental consideration. However if higher head is required, a minor modification to the final disinfectant pond (weir) can be designed accordingly to connect with effluent pipe to suit with both environmental and electrical characteristic requirements. For small hydropower such as micro hydro application the turbine head classification can be tabulated as Table 5.

Table 5 Head classification and suitable turbine types

Turbine types	Head Classification		
	High (> 50m)	**Medium (10 – 50m)**	**Low (<10m)**
Impulse	Pelton Turgo Multi-Jet Pelton	Cross flow Turgo Multi Jet-Pelton Francis	**Cross flow**
Reaction	-	-	Francis Propeller Kaplan

The application of cross flow turbine for lower head classification can be exemplified as shown in Figure 4 where the turbine is attached to the dynamo generator at the effluent discharge point to generate electricity. For power quality and to meet minimum electrical standard, the application of inverter or regulator can be opted before feedback the power generated to the electrical board.

Figure 4 The application of cross flow turbine at normal stream in Selangor

Since the normal operation of STP is using electricity for pumps, auxiliary appliances and other control application, the embedded micro hydro at the effluent discharge of STP is desired to generate electricity sufficiently for the STP own use. If the application is reliable and conveniently possible, the normal STP can be installing with this innovation to save on the electricity energy that is billed monthly to the operator. However, to validate the actual performance and constraints involves, further investigations include empirical data collection using a full scale installation at actual environment need to be employ besides the use of Computer Aided Design (CAD) simulation available in the market to capture all relevant information pertaining this technology which involves 2 engineering disciplines at one time. The ideal aim for the application can be illustrated as Figure 5.

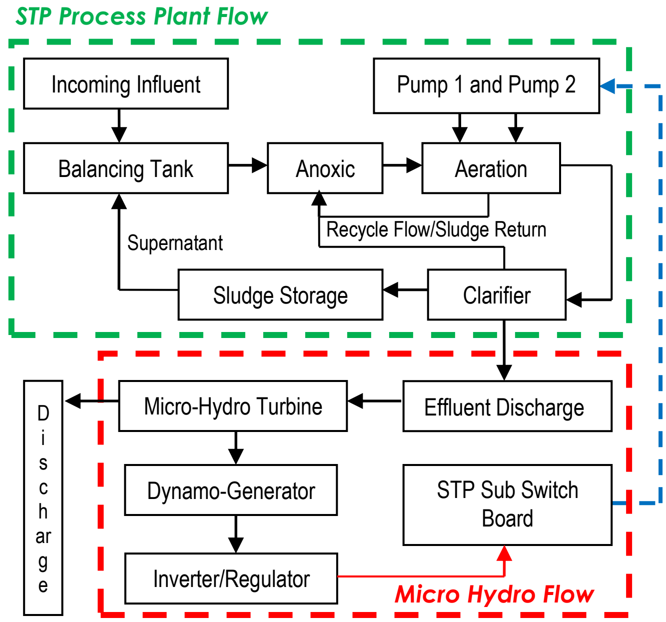

Figure 5 The ideal application of micro hydro embedded at effluent discharge point of STP.

If the overall STP plant can have a constant water flow from the wastewater treatment process and the electrical generator can work well in the application, the electrical power generation is possible to feedback to the STP electrical board panel for pumping and STP auxiliary application. Hence it will have a self-ecosystem in both water treatment and electrical generation and therefore provides alternative energy for the treatment plant to operate using its own flowing water from the wastewater treatment process (Figure 6).

Figure 6 The constant flowing water from effluent STP process, location at Nilai Northbound RSA, 375 PE (Courtesy by D'Bumi Water Sdn Bhd)

The stream and river categories in terms of minimum required flow rate (m^3/seconds) and water head (meter) that are suitable for micro hydro application can be illustrated in Figure 7 which includes very small stream, small stream, stream, small river and river [33].

Figure 7 Stream category, minimum flow rate and minimum head for micro hydro application [33]

Category	F/Rate	Head
Very small stream 	0.01 to 0.05 (m^3/s)	10 – 50 (meter)
Small Stream 	0.05 to 0.25 (m^3/s)	2.5 – 10 (meter)
Stream 	0.25 to 1.0 (m^3/s)	2 – 2.5 (meter)
Small river 	1.0 to 2.0 (m^3/s)	1.5 – 2.0 (meter)
River 	> 2.0 (m^3/s)	1.0 – 1.5 (meter)

By assessing at the STP water flow profile and the minimum required flow rate and water head as claimed by the manufacturer from Figure 6, it is hypothesized that the embedded micro hydro at STP effluent point is possible to materialize. However, a feasibility studies involve the power system studies (electrical) and effluent parameter studies (water flow) need to be conducted prior to site selected. The STP need to be working in maturity where internal ecosystem for the wastewater process is presence hence providing the constant quality effluent flow at the discharge point that is required to drive the micro hydro turbine. Next is to translate the application directly at the actual STP site with a full scale micro hydro installation, followed by an empirical data collection to explore the actual performance. Further research is needed with regards of the possible application of micro hydro embedded at effluent discharge point of STP to promote sustainable energy for future generations.

5.0 CONCLUSION

Wastewater treatment process involves the flowing water especially at the effluent discharge point where the potential energy is possibly harvested for electricity generation. The micro hydro application particularly the cross flow turbine is the most suitable option for micro-hydro low head application that is desired to perform the task. It was reported that IWK is operating more than 6000 STP plant in Malaysia [20] with the average of 3000 STP in the range of below 5000 PE, the actual potential of this application is significantly high. These numbers does not include the self-managed STP which is operated by individual owner. The exploration of the application using CAD followed by an empirical data collection, applies in the real full-scale in actual environment is highly desirable to explicit the factual potential of this inter-disciplinary technology. Therefore, future research is highly recommended in this area to validate the possible application of micro hydro electric generator which is embedded at the effluent discharge point of STP.

Acknowledgement

The authors acknowledged the informative contributions for this publication from Mega Jati Consult Sdn Bhd, D' Bumi Water Sdn Bhd, Suria Infiniti Sdn Bhd and Rapid Matrix Sdn Bhd. This research was presented to Persada PLUS (21th August 2015) and IWK Headquarters (2nd September 2015) for actual data and technology application review.

References

[1] Act 447. 1990. *Electric Supply Act 1990*. Government Printing, Kuala Lumpur.

[2] Efficient Management of Electrical Energy Regulation. 2008. Government Printing, Kuala Lumpur.

[3] SEDA-Sustainable Energy Development Authority of Malaysia, Function of SEDA Malaysia [Online]. [Accessed 21th August 2015]. Available from World Wide Web: http://www.seda.gov.my.

[4] Act 726. 2011. *Sustainable Energy Development Authority Act 2011*. Government Printing, Kuala Lumpur.

[5] Act 725. 2011. *Renewable Energy Act 2011*. Government Printing, Kuala Lumpur.

[6] Green Building Index [Online]. [Accessed 19th September 2015]. Available from World Wide Web: http://www.greenbuildingindex.org/.

[7] Energy Commission. 2014. *Annual Report 2014*. Energy Commission, Malaysia.

[8] Fulford, D. J, Mosley, P., Gill, A. 2000. Field Report: Recommendation On The Use Of Micro-Hydro Power In Rural Development. *Journal of International Development*. 12: 975-983.

[9] Harvey, A., Brown, A., Hettariachi, P., Inversin, A. 1993. *Micro-Hydro Design Manual*. Intermediate Technology Publication, London.

[10] Rijal, K. 1998. *Private MMHP In Nepal: A Country Paper*. ICIMOD.

[11] Joshi, R. D., Amatya, V. B. 1994. *Mini And Micro Hydropower Development In The Hindu Kush Himalayan Region-The Nepal Perspective*.

[12] Shresta, G. R. 1997. *Manual Of Rural Technology With Implications For Mountain Tourism*.

[13] M. Pauzi M. Kassim, Karam M. Al-Obaidi, M. Arkam C. Munaaim and Abd. Mokhti Salleh. 2015. Feasibility Study on Solar Power Plant Utility Grid under Malaysia Feed-in Tariff. *American Journal of Engineering and Applied Sciences*. Science Publication.

[14] Suruhanjaya Perkhidmatan Air Negara. 2014. *Garis Panduan Industri Pembentungan Malaysia (Jilid II) Prosedur Kerja-Kerja Pembentungan*.

[15] Suruhanjaya Perkhidmatan Air Negara. 2013. *Garis Panduan Industri Pembentungan Malaysia (Jilid II) Prosedur Kerja-Kerja Pembentungan*. Edisi ke 2 Pindaan V1.

[16] ISO/IEC 17025:2005. 2010. *General requirements for the competence of testing and calibration laboratories*. International Standardization Organization, Geneva.

[17] Act 214. 2006. *Water Services Industry Act*. Government Printing, Kuala Lumpur.

[18] Regulation: *Water Services Industry (Planning, Design and Construction of Sewerage System and Septic Tank)*, 2013, Government Printing, Kuala Lumpur.

[19] SPAN TS 1402:2010. 2013b. Technical Specification, Sewage Treatment System, Part 2: Construction and Installation-Packaged Plants, Technical Standards and Compliance Division Sewerage Regulatory Department.

[20] Indah Water Konsortium. 2015. [Online]. [Accessed 25 September 2015]. Available from World Wide.

[21] Licensee Supply Regulation. 1990. *Act 447 Electric Supply Act 1990*. Government Printing, Kuala Lumpur.

[22] Electricity Regulation. 1994. *Act 447 Electric Supply Act 1990*. Government Printing, Kuala Lumpur.

[23] *Occupational, Safety & Health Act 1994*. Government Printing, Kuala Lumpur.

[24] Malaysia Standard MS IEC *60364 Electrical Installation of Buildings*. Malaysia.

[25] *IEE Wiring Regulation*. 16th Edition. IEE. UK.

[26] *Electricity Supply (Successor Company) Act 1990–Act 448*. Government Printing, Kuala Lumpur.

[27] Indah Water Konsortium. 2007. *Electrical Works Specifications*. Issue 1 (Rev 1): PED/SDQS/EWS/SPEC/ 0507/003.

[28] A. H. Elbatran, O. B. Yaakob, Yasser, M. Ahmed, H. M. Shabara. 2014. Operation, Performance And Economic Analysis Of Low Head Micro-Hydropower Turbines For Rural And Remote Areas: A Review. *Renewable and Sustainable Energy Reviews*. Elsevier. 43: 40-50.

[29] Paish, O. 2002. Small Hydro Power: Technology And Current Status. *Renew Sustain Energy*. 6: 537-556.

[30] Ghosh, T. K. & Mark, K. P. 2011. *Energy Resources And Systems. Renewable Resources.* Netherland: Springer (Chapter 3).

[31] Edy, E. Jiménez. 2009. Final Study Report, Achievable Renewable Energy Targets For Puerto Rico's Renewable Energy Portfolio Standard. Puerto Rico: Puerto Rico's Energy Affairs Administration.

[32] Date, A., Aliakbar, A. 2009. Design And Cost Analysis Of Low Head Simple Reaction Hydro Turbine For Remote Area Power Supply. *Renew Energy*. 34: 409-415.

[33] *Estimating Head And Flow* [Online]. [Accessed 21th September 2015]. Available from World Wide Web: http://www.micro-hydro-power.com/micro-hydro-power-Estimating-Head-and-Flow.htm.

[34] Environmental Quality Act. 1974. Government Printing, Kuala Lumpur.

[35] Malaysia Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979, (Rev 1999, 2000) Government Printing, Kuala Lumpur.