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Two water wheels performance in series for empowerment of irrigation

Asral ¹, F Huda ¹ and M Akbar ¹

¹Department of Mechanical Engineering, Universitas Riau Pekanbaru, 28291, Panam, Indonesia

Email: asral@lecturer.unri.ac.id

Abstract. Irrigation system especially in Riau Province are widely available in around of agriculture area. The water flow of irrigation seems to provide continuous energy however many people ignored. The source can be used to drive some water wheels to generate electricity. The head of flow is relatively low with long enough area as the reason many water wheel in series like undershot type was appropriate to apply. This study aims to investigate the possibility of using many water wheels in a canal by installing two units of water wheel together i.e picohydro with series. Then, doubling the amount of energy might be utilized from the resources. For manufacture the corrosion resistant and lightweight material are selected to maintain the wheel from damage. The water wheel was tested from the ground up irrigation keep constant, various level of water to determine the characteristics of water wheel achievement. Power output and efficiency of the water wheel are among other of the results present in this study. Single water wheel produce that the maximum electrical power of about 1300 Watt. However the installation of two water wheel in series caused a decrease the total output power of the system approximately 1065 watt.

1. Introduction

The flow water in small river or irrigation provide the renewable energy but not yet widely used. In last decade, many irrigations system has been developed in Riau province in order to irrigate 250,571 ha of lands. However, the people who has live at around it have a problem with electrical power supply and many cases the irrigation has damaged. The damage lead to water resources has only slightly reach the lands. This condition requires the problem solving because it may affect the people economically and their survival.

The irrigation in good condition are likely to have great potential to be utilized as a power generation. In addition, based on the data from the energy ministry of human resources, throughout of Indonesia's territory available hydropower potential are about 75.5 GW with installed capacity of 4.7 GW [1]. Therefore the potential energy contained in the irrigation is much possible used to drive some small-scale water turbines. While in area with degraded irrigation might be also develops the spiral water pump. In order to establish both water and electricity issues, the incorporation concept of water turbine with pump are proper devices to developed [9].

The length of irrigation channels were great course also provides a large amount of potential energy as well. Although likely to be able to move small-scale turbines but if made many turbines would generate large amounts of energy. If only every 200 m on irrigation channels built a small-scale plant would have generated thousands of watts of electrical power without disrupting water needs for agriculture. Many studies have been conducted on the utilization of energy as well as setting the energy requirements on small-scale water channel such as efficient water and energy usage for modernization irrigation [2]. Regulation and optimizing the use of water resources for consumption, irrigation and hydroelectric power plant [3]. Then the effort to improve the energy production by water power plant is also a study concern with applied the combined water cycle power generating system [4].

A study that aims to develop a new type of turbine has been delivered by Li *et al* [5]. Turbines are developed according to an open channel area with a small head like a small stream or canal irrigation



farming in order to buffer used for hydroelectricity. For the use of water cross flow turbine has undershot type into consideration. As a result, a significant simplification is realized by making the turbine without the casing. However, the flow field of water cross-flow turbine type undershot move somewhat complex with free surface. This means that the depth of the water around the runner turned to variations in rotational speed, and the flow field itself is complex and changes with time. Therefore it is necessary to better understand the flow field around a water turbine with a free surface, in order to improve the performance of a turbine of this type. Furthermore, the performance of the water turbine made determined and the flow field visualized using particle image velocimetry (PIV) techniques. The results showed that, the depth of the water between the outer and inner diameter of the runner decreases when the rotational speed increases. In addition, the speed of fixed-point at a different angle on the inlet and outlet area of the first stage and second extracted.

Pico hydro water turbine is an alternative technology for generating electricity from a hydroelectric plant small size. It is suitable for use in rural areas because of the construction cost and the technology used is conventional. A research report prepared by Keawsuntia [6] presents the design and results of testing of a power plant of water pico crossflow turbine, and to store the energy in batteries 12 V. An examination pico crossflow turbine with turbine wheel diameter of 0.8 m and 20 blade has the shape of a semi-circle diameter of 0.1 m, the length of the blade is 0.8 m, tested in a river. The results show that the system generates a maximum electrical power which is 145.42 watts or 3:49 kW-hours per day, which is enough to supply up to 6 families in a small community in rural areas. While the rate of return for electricity generation is reaching \$ 0023 per kW-hour.

Like a lot of research and studies conducted around the world to explore a variety of alternative and renewable energy sources, this study presents a description of the initial testing performed on the prototype pico hydro generator system for the purpose of investigating the performance [7]. The kinetic energy contained in the flow of water in domestic pipes are known to have the potential to generate electricity for energy storage purposes while performing routine activities such as laundry, cooking and bathing. The water pressure and water flow in the pipe from the main tank utility, which is used for the activities of everyday life, used for small-scale hydro turbines rotate to drive a generator for generating electricity. The test results indicate that the readings are significantly convincing in terms of electrical voltage recorded since it can be calculated to be followed is this system is feasible for electrification aimed at storage of energy and showed good prospects for improvement and further research in the future.

A study was conducted by designing appliances small hydroelectric power plants based on an analysis of the technological characteristics and shortcomings of existing hydropower [8]. As a supplement to conventional power plants, this device can be used in places where the state does not have a dam but it has plenty of water resources. The working principle of the new devices are introduced and the analysis of motion and force are made. Schematic design proves its feasibility through theoretical analysis. Tests on the model showed that the new hydropower has a high efficiency.

In order to explore new energy resources and utilization the irrigation where energy is provided free of charge, the development of small-scale hydro power into a proper object to be investigated. The research will be focused on designing small-sized water wheel rated in accordance with the existing potential based on previous study. Then determine of performance the power generator by testing in a specified place. If possible, some water wheel could be produced when the area is found broad narrow but long enough. Picohydro water wheel can be installed sequentially in the direction of flow is a method that can be done to get the energy from water over the maximum. The method of use of water wheel with more than one in a canal is to be a new thing in this study.

2. Methods

This field study located at Koto Tibun Village. The experiment carried out by various conditions of water wheel placed in the irrigation, namely: the main water wheel, main and second wheel installed in series. The water wheels were fabricated in Mechanics Technology laboratory of Riau University. Second wheel have outside diameter a half than main wheel. Four steps of pulley-belt mechanical

power transmission system are applied. The experimental conditions are described in Figure 1 and Figure 2.

In the main water wheel of the test, parameters measured were rotation, water level, flow, and electrical voltage output. Measurements were conducted for every hour. This works in order to investigate the energy availability of water flow as resources that might affect on water wheel performance.

In the condition of water wheel series, two water wheel are installed sequentially in the direction of flow. One of wheel situated close the entrance side dams, and the second one on behind downstream. Experiment parameters measured equal to the method of one wheel. In throughout study, the data was collected for all conditions respectively.



Figure 1. The arrangement of water wheel apparatus in irrigation



Figure 2. Rotations and Voltages measurement

3. Results and Discussion

In this test, H is the height of the water level was adjusted from the maximum height of water level that can be accommodated in the irrigation channel until the water level could no longer work the water wheel. Meanwhile H is a representation of the state of flow in the irrigation ditch where the height difference (head flow) has remain constant. Then the generator rotation is measure of shaft rotation on the shaft generator. Electricity voltage in volts is the voltage that is measured at the output terminal of the generator. The data collected from the measurements depicted in graphic form as will be described below.

3.1 With Single Water wheel.

The increase in water level resulting in an increases in the rotation of generator, as shown in Figure 3. The image illustrates the relationship between the two parameters of the test for the main water wheel installed single. The increase in the amount of water flowing per second, more and more energy is sourced from water provided for drive water wheel. The overall water will push the wheel blades resulting in a rotation on its shaft is transmitted to the generator. In accordance with the state of irrigation canals on the location of the change in water level can only be achieved as the maximum water level equal to the length of the blade.

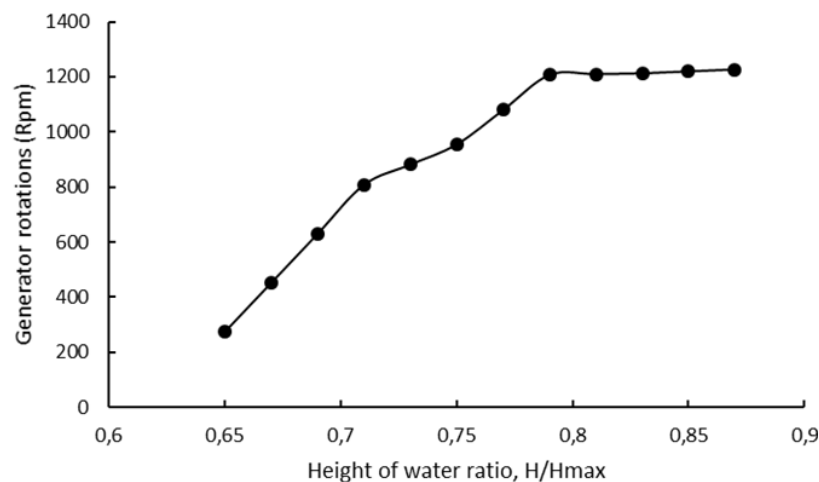


Figure 3. Characteristics of the generator rotation with single wheel to the height of water level

Furthermore, the increase in water level makes the line voltage that is obtained increases, as shown in Figure 4. When the ratio of water height to the maximum channel height, maximum electric generator produces a voltage of about 145 volts. Furthermore, if the ratio of this height is reduced, the electrical energy generated also seem to be significantly until it reaches zero volt. This graph shows that the electrical power can generated by the generator depends solely on the availability of water.

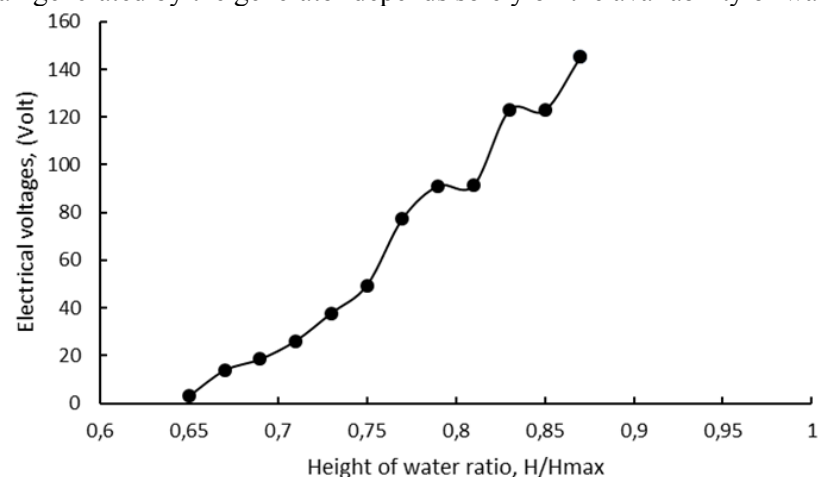


Figure 4. Characteristics of the electrical voltage with single water wheel to the water level

The electricity voltage is a function of the rotation, it is a state that has already prevalent in the science of electricity power. Because the rotation may cause the magnetic field on the plants which were removed in the form of voltage. The data like that depicted in Figure 5, where the relationship between the two in the form of a non-linear function. As apparent from the figure that the maximum voltage is achieved about at 1300 rpm.

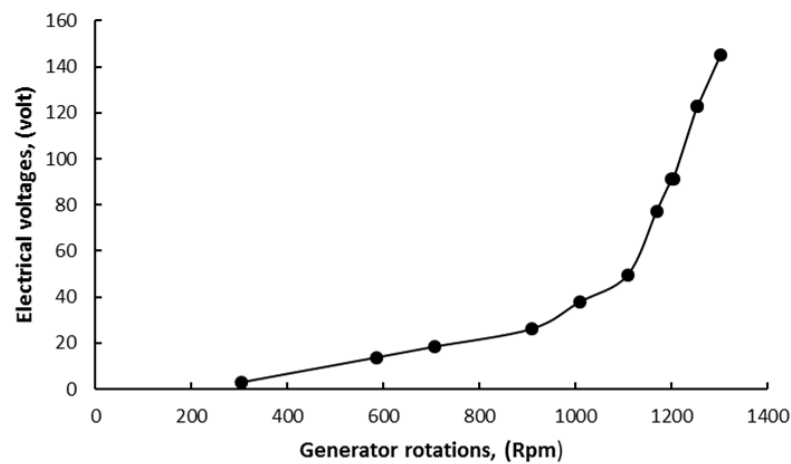


Figure 5. Characteristics of electrical voltage on certain generator rotation with single water wheel

3.2 Two Water wheel in series

Water wheel installed in series its means sequentially towards the flow of running water. As seen in Figure 6, show the characteristics of the main wheel as the height of water level has change as the flow entering the water wheel lap when it installed in series with a second wheel. The trend line shows the same state as water wheel installed itself however seen a decrease in the achievement of the maximum rotation of electricity generator about 1200 rpm. This indicates, the installation of a second wheel though smaller than main water wheel may affect the performance of the main wheel has located at upstream. Water on the downstream side of the main wheel slowdown due to the head flow differences was decreases.

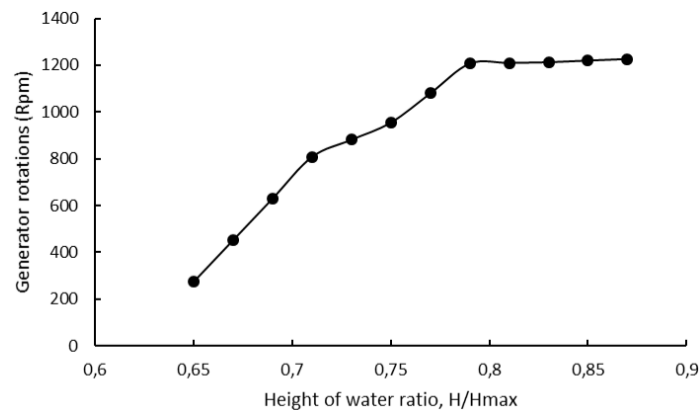


Figure 6. Characteristics of the generator rotation to the height of water level with water wheel in series.

Furthermore, changing the height of the water inlet on the water wheel blades are also cause changes in electrical voltage. However as the main wheel installed in series with the second are shows a decrease in the achievements of its maximum voltage, which in this case is about 115 volts. The data as shown in Figure 7.

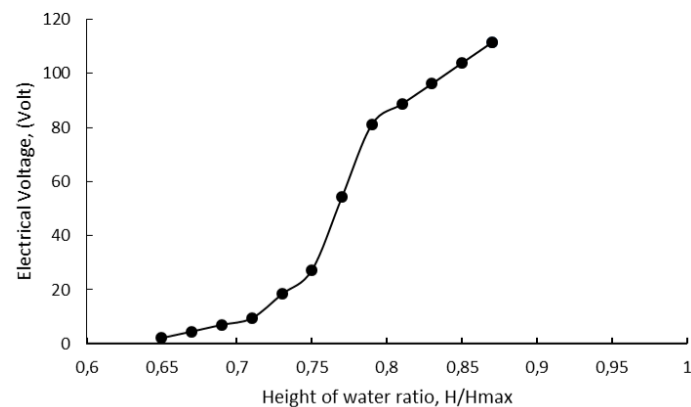


Figure 7. Characteristics of electricity voltage with water wheel in series to the height of water level

The higher the rotation will produce the voltage that is higher as well. As seen in Figure.8, shows the characteristic of rotation against electricity power by the main water wheel on the state installed series with a second wheel. It is evident here that the existence of a second wheel seems to cause a decrease in electricity power output.

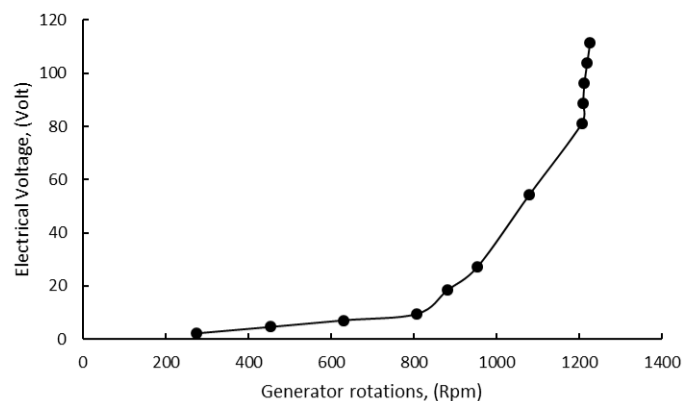


Figure 8. Characteristics of the electricity voltage to the generator rotation with water wheel in series

Meanwhile, when viewed from the side of the second wheel, characteristic changes in the water level of the rotation generator showed the same trend with the main wheel (Figure 9). However in a smaller scale. The rotation decreased significantly when compared with the main wheel. At a height of water ratio of water level achieved maximum at about 0.725, second wheel could cause the generator rotates about 325 rpm. These results indicate that the energy of the water that reaches the wheel was reduced as a part of it has absorbed by the main wheel due to positioned at upstream of flow.

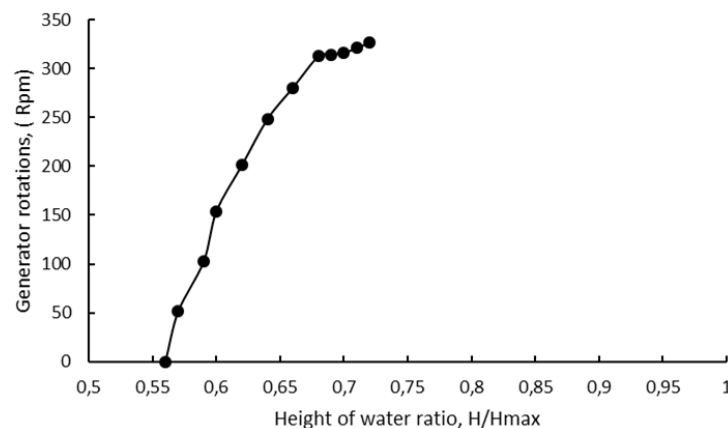


Figure 9. Characteristics of the generator rotation to the height of water level with water wheel in series

Increasing in the height of water ratio causes an increase in the electricity voltage as shown in Figure 10. The ratio of maximum water level can generate the electricity voltage by the second wheel was about 13 volts. This data indicate that as the height of water ratio increase has produce insignificant change on electricity voltage by second water wheel.

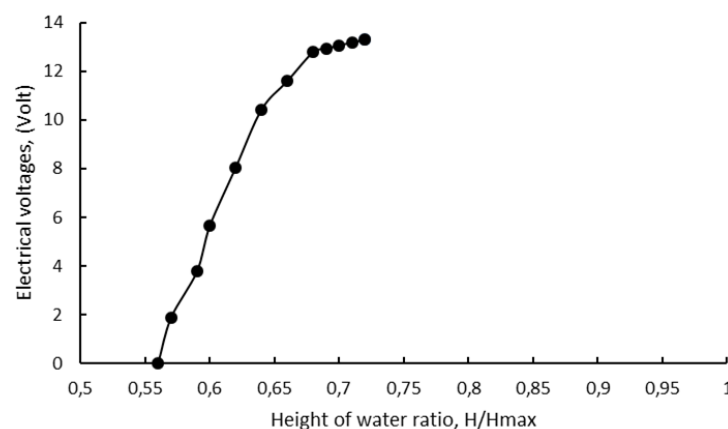


Figure 10. Characteristics of the electricity voltage to the height of water level with water wheel in series

Figure 11 presents the influence of rotation on the electricity voltage output of system with water wheel series. This data showed that the trend of parameters seems to proportional. The data was derived from a rather low rotation so it looks like a linear relationship. As it compared with the result of the main water wheel particularly in condition of low rotation show similarities. Thus it can be predicted here that these symptoms has temporary effect, however as the rotation increased then the trend show as the general relationship between of rotation and voltage.

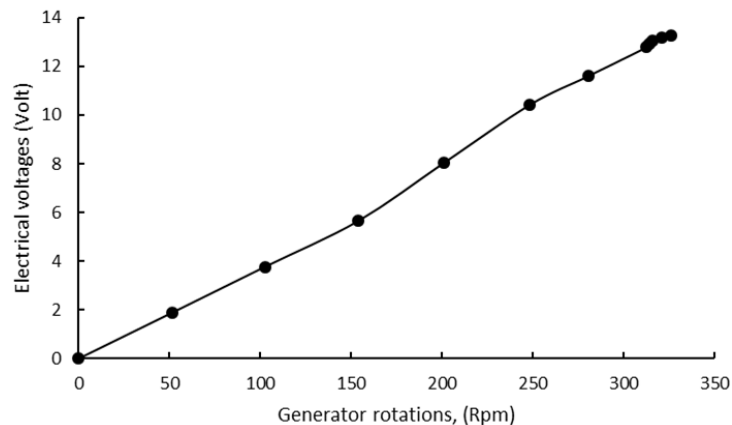


Figure 11. Characteristics of the electricity voltage to the generator rotation with water wheel in series

4. Conclusions

This study reveals the performance of two undershot water wheel installed in series applied particularly on rural irrigation. The conclusion can be drawn are:

1. As electrical generator the water wheel is agree installed in irrigation system more than one sequentially, however take into consideration of spacing between wheel.
2. The maximum power produced with single wheel is about 1300 Watts, however when installed as series are decreases to 1065 Watts.
3. For single and series water wheel conditions, the power are decreases as the water level decreases.
4. The power generation with water wheel of series less than single approximately 23%. Total electricity power produce by water wheel series was 18% lower than single main water wheel.

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References

- [1] BPPT, (2012). "Outlook Energy Indonesia". Energy Ministry of Human Resources Republic of Indonesia.
- [2] Tarjuelo, José M., Rodriguez-Diaz, Juan A., Abadía, Ricardo, Camacho, Emilio, Rocamora, Carmen and Moreno, Miguel A., (2015). Efficient Water and Energy Use in Irrigation Modernization: Lessons from Spanish Case Studies, Agriculture Water Management, Int. Journal, 162, 67-77
- [3] Wu, Yiping, and Chen, Ji , (2013). Estimating irrigation water demand using an improved method and optimizing reservoir operation for water supply and hydropower generation: A case study of the Xinfengjiang reservoir in southern China, Agriculture Water Management, Int. Journal, 116, 110-121
- [4] Liu, Yue, and Packey, Daniel J., 2014. "Combined-Cycle Hydropower Systems - The Potential of Applying Hydrokinetic Turbines in The Tailwaters of Existing Conventional Hydropower Stations", Renewable Energy, Int. Journal, 66, 228-231
- [5] Li , Yanrong, Nishi ,Yasuyuki, Inagaki, Terumi dan Hatano, Kentarou. 2014 " Study on the Flow Field of an Undershot Cross-flow Water Turbine". Applied Mechanics and Materials Vol. 620, pp 285-291
- [6] Keawsuntia, Yuttachai. 2014. "Design and Test of Pico Crossflow Turbine for the Generation of Electricity for Use in the Rural Area". Applied Mechanics and Materials, Vols. 496-500, pp 605-608

- [7] Ridzuan, M.J.M., Hafis ,S.M., Azduwin, K., Firdaus ,K.M., dan Zarina, Z. 2014.” Development of Pico-hydro Turbine for Domestic Use”.Applied Mechanics and Materials, Vol. 695, pp 408-412
- [8] Zhang, Lizhen, Cao, Xiaolong, Li, Juntao, and Wu, Shulei. 2012.” Design of New Small Hydroelectric Device”. Advanced Materials, Vols. 472-475, pp 883-886
- [9] Asral, Akbar, Mustafa, and Syafri. 2017. “The Performance of Undershot Water Turbine Combined With Spiral Tube Pump On Empowerment of Energy Resources Local Contiguous Small River” Journal of Ocean, Mechanical and Aerospace-Science and Engineering, Vol. 42, pp 19-23.