UNIVERSITI TEKNOLOGI MARA

DESIGNATION AND EVALUATION OF ENCLOSED GRAVITATIONAL WATER VORTEX TURBINE (GWVT) AT HORIZONTAL ORIENTATION FOR MICRO HYDROPOWER GENERATION

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ABSTRACT

A sustainable electricity power supply is crucial, especially for a small population in a rural area. Micro hydropower generation in rural areas is important to ensure electricity can be provided, especially in off-grid areas. This study aims to predict power produced from conical gravitational water vortex turbine (GWVT) via horizontal orientation. Thus simulations were carried out before and after the actual turbine experiment to ensure the validity of the results produced for power output predictions through mathematical modelling. This study's conical GWVT was designed in a fully enclosed system with a conical turbine casing. During the simulation phase by using SOLIDWORKS Flow Simulation, two different turbine orientations were simulated, i.e. vertical and horizontal at different blade angles design (25°, 45°, 75°, 90°, and 120°), and with a different number of blades, i.e. 8, 12, and 18, while forces were harnessed as the selection criteria to find the optimum turbine setting. The optimized setting from the simulations was adapted for actual fabrication. The turbine underwent various flow rate tests, i.e. 0.0053 m^3/s, 0.006 m^3/s, 0.0063 m^3/s, and 0.00645 m^3/s, and loading conditions, i.e. 1kg increment until the shaft completely stop turning to obtain its performance curve. Then, validation of actual experimental results was done through simulation using MRF method in SOLIDWORKS Flow Simulation. The outcome of the actual turbine experiment was then modeled through multiple linear regression using the Minitab software. The simulation results showed that it was possible to run and produce force from horizontal conical GWVT designed in a fully enclosed system. It was found that vertical turbine orientation produced slightly higher force than horizontal orientation using runner blade of 90° angle and 12 blades where the distributed forces were 15.31 N and 14.12 N, respectively, at tangential (z-axis) direction. The maximum power produced was 69.39 W, while efficiency of the turbine was calculated at maximum 16.06% which was achieved at angular velocity of 12.71 rad/s and torque of 5.47 N.m. For validation of actual turbine experiment and simulation, results shown that the simulation can produce accurate torque predictions at higher angular velocity settings i.e. 15–30 rad/s within +1 N.m discrepancies from actual turbine results but under prediction occurs at low angular velocity settings i.e. 0-15 rad/s within -6.1 N.m discrepancies. The regression equation P=89.9+7.32X1+24.25X2-11.23X3 achieved R^2 of 55.36% and overall power output prediction accuracy of 73.43%. The results are helpful to predict the performance of conical GWVT, prior to actual implementation.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

The global electricity demand since 1980s has doubled every 14.5 years, with the annual energy increment rate averaging around 4.93% (Azimoh et al., 2016). In Malaysia, the current electricity generation capacity is 30 gigawatt. The output electricity demand periodically in Malaysia is within the maximum of 17000 Megawatt, known as the demand limit (Oh et al., 2018). Based on the year 2013 capacity data available, the distribution of energy sources in Malaysia is currently using 88.4% fossil fuel while 11.4% is hydropower (Haiges et al., 2017). This exhibits that Malaysia still depends largely on conventional fossil fuel sources as their primary energy source. As a continuously developing country, it is common to see an increase in energy demand as it goes with the country's development.

Issues on minimal rural electrification in Malaysia at present have always been evident in this country. The standard of electricity distribution in rural areas, especially Sabah and Sarawak, is 79% in comparison to 99.62% of Peninsular Malaysia (Borhanazad et al., 2013). From the total of thousands of schools in Malaysia, 809 of them are not connected with electricity. Most of them are found in Sarawak and Sabah, with no foreseen solution to connect these schools with electricity grid within the next five to ten years (Muhaimin Mahmud, 2011). Thus, the development of a hybrid system between the abundance of renewable power resources in Malaysia can aid the electrification of rural locations that are not connected to the grids (Hossain et al., 2015),(Elbatran et al., 2015). Renewable energy is mainly an element of the vast and limitless source. They fall into categories such as biomass, wind, solar, hydropower, and tidal energy (Shahzad, 2015).

One of the available micro-hydro turbines is the Gravitational Water Vortex Turbine (GWVT) which harnesses energy from its vortex. By following the designs setup for GWVT, it is possible to produce a vortex in the casing i.e., cylindrical or conical basin. The GWVT are one of the micro-hydro turbine which falls into the impulse turbine classification. The GWVT integrates an artificially induced Free Surface Vortex (FSV) (Yaakob et al., 2014a). The basic operation principle of this