PERFORMANCE INVESTIGATIONS OF HYBRID CROSS FLOW HYDROKINETIC TURBINE

Ph.D. THESIS

by

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ABSTRACT

Various types of rotors are available for cross flow hydrokinetic turbine which work on the principle of lift and drag forces. Hybrid rotor configuration is the combination of two conventional hydrokinetic rotors viz. Darrieus and Savonius. Very few studies on the system parameters investigations of hybrid configuration of cross flow hydrokinetic turbine are carried out and reported in the literature. The installation conditions for hybrid hydrokinetic turbine have not been investigated so far. Under the present study, a hybrid configuration of cross flow hydrokinetic turbine rotor was proposed to investigate its performance with the objectives of (i) To develop a model of hybrid cross flow hydrokinetic turbine with considered system design parameters, (ii) To investigate numerically the modelled hybrid cross flow hydrokinetic turbine under different flow velocity, (iii) To design and fabricate of experimental set up and hybrid hydrokinetic turbine model for the validation of CFD results, (iv) To investigate numerically the effect of various system parameters such as attachment angle, radius ratio, blockage and clearance ratio under different flow velocity, (v) To develop correlation for coefficient of power in terms of system parameters of hybrid rotor.

Numerical simulations based study has been carried to investigate the performance of the hybrid rotor hydrokinetic turbine by considering the various system and installation parameters. System parameters include the radius ratio and attachment angle while the installation parameters are considered as clearance ratio and blockage ratio. The power coefficient of the turbine has been investigated for a range of water velocity of 0.5 m/s to 2.0 m/s. Rotational velocity of the turbine was varied by taking different values of TSR in the range of 0.2 to 1.4.

To achieve the proposed objectives of the study, 3D model of the hybrid rotor along with the channel was prepared and simulations were carried out by using the ANSYS-CFX solver along with RNG k-ε turbulence model. To simulate the rotating behaviour of the turbine rotor, ‘Mesh motion’ and ‘Frozen rotor’ approach was applied for transient and steady simulations respectively.

To validate the numerical simulation results, a model of hybrid rotor was designed, fabricated and tested through experimentation. The power coefficient was calculated based on

the torque generated by the turbine rotor. The simulation results are compared with experimental results and it is found that the results follow the similar trends. The pressure and velocity contours obtained in the present simulation analysis have also been compared with the earlier published results and similar trends have been observed. Simulations were carried out to investigate the effect of the parameters on the performance of the turbine. Based on simulation results it is found that a pressure wave was formed which moves toward upstream side which is generated due to blockage of water path by the blade. In case of Savonius rotor, negative pressure zone is developed in the rare side of blade which leads to flow recirculation. The low pressure zone gets diminished as radius ratio increases.

Based on the velocity contours obtained it is found that velocity is reduced at the trailing edge of Darrieus rotor blade which starts to regain itself by sharing the kinetic energy from the upstream water flow. Reduction in velocity is also caused due to fluid mixing which is responsible in substantial energy loss due to viscous force resistance developed between two consecutive layers of water. The variation in the velocity magnitude and direction of flow results in development of force on the rotor structure. The position of blades assures the development of force in a defined direction. The performance of the turbine is evaluated in terms of power coefficient (C_P) and torque coefficient (C_T). It has been found that power coefficient increases with the increase of blockage ratio. In case of radius ratio, power coefficient attains a maximum value corresponding to radius ration value of 0.6 at clearance ratio and attachment angle of 0.55 and 90° respectively.

Using the simulations data, an attempt has also been made to develop a correlation for power coefficient as function of system, installation and operating parameters of hybrid hydrokinetic rotor. The simulations carried out under the present study may be useful for further investigations on the performance of hybrid hydrokinetic turbine under future studies. The results may also be helpful for better installations of hybrid hydrokinetic turbines under different site conditions.