2022 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS) | 978-1-6654-9581-3/22/$31.00 ©2022 IEEE | DOI: 10.1109/I2CACIS54679.2022.9815269

Hybrid HCS-Fuzzy MPPT Algorithm for Hydrokinetic Energy Harnessing

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***Abstract*— This paper proposes a hybrid maximum power point tracking (MPPT) algorithm for the stand-alone hydrokinetic technology in river application. The fixed step-size Hill Climbing Search (HCS) algorithm is widely used due to its simplicity. However, the operating point oscillates around the maximum power point (MPP) during dynamic steady-state resulting waste some amount of energy. The proposed algorithm is the combination of the Fuzzy Logic Controller (FLC) and HCS algorithm to provide the variable step-size to eradicate the limitation of conventional HCS algorithm. The proposed algorithm has been compared with the Small Step HCS (SS-HCS) to investigate the performance of the algorithm. The simulation results illustrated the proposed algorithm (Fuzzy-HCS) improved the output power with 89.91 % efficiency and minimizes oscillation during dynamic steady-state.**

Keywords—MPPT, hydrokinetic, Fuzzy Logic Controller, Hill-Climbing Search

I. INTRODUCTION

The energy harvesting through renewable energy sources has received significant interest due to the environmental concerns and exhaustion of fossil fuels. Instead of the solar photovoltaic (PV) and wind energy conversion system (WECS), the hydrokinetic energy harnessing system also has been investigated for clean and future energy sustainability [1] .

Hydrokinetic energy harnessing is an electromechanical device that extracts energy from the flowing of water. The system produces the electricity without the requirement of dams and the associated infrastructure when compared to the conventional hydropower generation [2]. The system can be applied in the river, tailwater, water sewage treatment or man-made channel [3], [4].

The output power from hydrokinetic is differing because the power generation will be affected by the fluctuation in water speed. Therefore, to capture the maximum energy at the minimum cost is a big challenge in this field. Hence, the used of maximum power point tracking (MPPT) algorithm is required to be implemented in the controller design.

The MPPT algorithm for the stand-alone hydrokinetic has been inspired by solar PV and WECS. In addition, the concepts of operation, electrical hardware and variable speed capability for the generator are similar to WECS [2], [5], [6]. Thus, the MPPT algorithm from the WECS has been the main reference for details research in this field.

Several researchers have proposed different MPPT algorithm and control strategies to control the hydrokinetic technology such as in [7]–[14]. In [7], Fuzzy-PI has been implemented to control the pitch angle on variable pitch hydrokinetic turbine. In[8],and [11] the P&O MPPT algorithm have been applied to control the rotational of generator at optimum speed. In [9], Modified Hill-Climbing Search (MHCS) MPPT +PI controller is presented and able to improve the extraction energy with 96.32 % efficiency. The adaptive MPPT algorithm is presented in [10] using the super-twisting sliding mode control, while in [13] the adaptive step-size based on HCS MPPT algorithm is proposed.

On the other hand, control strategies for grid connected hydrokinetic technology is applied using Rule-Based control algorithm for uncertainties load demand [12]. While in [14] a modular hydrokinetic smart grid by maximum current control is applied to increase the output power of microturbine arrays.

This paper proposes a design topology for the hydrokinetic turbine with variable step-size HCS-Fuzzy MPPT algorithm to harness the maximum power and reduced the oscillations during dynamic steady-state. The design topology consists of PMSG, uncontrolled rectifier and the boost converter as a control circuit to control the output power of the system. By this method, the output voltage and current are constantly measured and updated by the algorithm. By varying the duty ratio of the boost converter, the output voltage will change as a result will change the rotational speed of the generator.

II. HYDROKINETIC TECHNOLOGY CONFIGURATION

A. Circuit Topology

The hydrokinetic technology consists of a water turbine, PMSG and power electronic converters such as a rectifier and DC boost-converter as shown in Fig. 1 [14]. The circuit topology and physical hardware remains the same and are commonly used by small wind turbine energy conversion system (SWECS) as well as in a tidal energy system [15]–[17]. With regards to the current topology, the direct coupling of PMSG with a water turbine (without a gearbox) gives rise to a high-efficiency system [18].