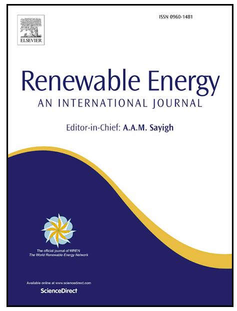
Accepted Manuscript



Evaluation of loss effect on optimum operation of variable speed micro-hydropower energy conversion systems

Hossein Iman-Eini, David Frey, Seddik Bacha, Cedric Boudinet, Jean-Luc Schanen

PII: S0960-1481(18)30919-4

DOI: 10.1016/j.renene.2018.07.122

Reference: RENE 10396

To appear in: *Renewable Energy*

Received Date: 20 April 2018

Revised Date: 24 June 2018

Accepted Date: 25 July 2018

Please cite this article as: Iman-Eini H, Frey D, Bacha S, Boudinet C, Schanen J-L, Evaluation of loss effect on optimum operation of variable speed micro-hydropower energy conversion systems, *Renewable Energy* (2018), doi: 10.1016/j.renene.2018.07.122.

Evaluation of Loss Effect on Optimum Operation of Variable Speed Micro-hydropower Energy Conversion Systems

Hossein Iman-Eini[1], David Frey[2], Seddik Bacha[2], Cedric Boudinet[2], and Jean-Luc Schanen[2]
[1] School of Electrical and Computer Engineering, College of Engineering, University of Tehran, Tehran, Iran
[2] Grenoble Electrical Engineering Laboratory, Grenoble Alpes University, 38402 Grenoble, France
Corresponding author e-mail address: imaneini@ut.ac.ir

Abstract- This paper evaluates the effect of converter and generator losses on the maximum power point (MPP) of variable speed micro-hydropower energy conversion systems. As a case study, a semi-Kaplan micro-hydropower turbine with a permanent magnet (PM) generator and a back-to-back full converter is considered. Using the analytical model, different loss terms, such as converter losses, PM generator losses and mechanical losses are calculated at different shaft speeds. Then, the curves of turbine power and injected power to the grid are extracted as a function of turbine speed. It is shown that the maximum attainable power of the variable-speed hydropower system does not correspond to the MPP of hydraulic turbine. In other words, to get the maximum power from the whole hydropower system, it is necessary to consider power losses of the electric generator and power electronic interface between the turbine and the grid. These power losses can change the power-speed characteristics or MPP location of the hydropower system. According to this fact, the conventional MPP tracking (MPPT) algorithms which try to track the MPP of hydraulic turbines fail to extract the maximum power. Hence, a modified perturb and observe (P&O) MPP tracking algorithm is proposed for the variable speed hydropower systems to increase their efficiency. The modified tracking algorithm finds the “optimum MPP” automatically and without the extra calculations. Also, the injected power to the grid is increased 3.7% when the modified algorithm is applied to the studied case study. Finally, the validity of theoretical claims is verified by experimental tests on a 5 kW hardware prototype.

Keywords- Full converter, Loss calculations, Micro-hydropower, MPPT algorithm, Permanent magnet synchronous generator, Variable speed hydropower system

1- Introduction

Hydropower is one of the earliest and most commonly used renewable sources of electricity in the human life. It represents more than 16% of the global electricity generation [1], and is the largest global renewable energy source [2]. This source of energy can be converted to electricity via the hydraulic turbine and electric generator. The size of hydraulic turbine may vary from several KW to hundreds of MW, where the term micro-hydropower is used for the turbines with a capacity lower than 100 kW [3]. In micro-hydropower stations, the plant is usually installed in a run-of-river manner with a small reservoir or no reservoir and the water head is low. Such hydropower stations represent an environmentally friendly solution, since they do not interfere with the rivers flows [4].

The early hydropower stations were of fixed speed type. This kind of stations suffers from two main problems: 1-inability to produce power in the whole range of water head and 2-low efficiency in partial generation or under off-design operating condition [5]. Some references have focused on the hydraulic design and flow characteristics optimization of hydraulic machineries to increase efficiency and reduce energy loss. In [6], unsteady cavitation flows under off-design conditions and their impacts on the efficiency and the operational stability are studied. In [7], a systematic investigation into the influence of tip clearance size on energy performance and pressure fluctuation for a mixed-flow hydraulic machine is conducted. Ref. [8] evaluates the role of blade rotational angle in the energy performance and pressure fluctuation of the mixed-flow hydraulic machine through an experimental measurement and numerical simulation.

By recent advances in the power electronics, the variable speed operation can be employed for the hydropower systems similar to modern wind turbine energy conversion systems (WTECs). This technology allows