# Effects of Water Injection on Generator Output Power Augmentation in a Microturbine

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**Long Abstract**

## Introduction

Microturbines are still in a difficult situation with respect to their spread in the market because of their low electric efficiencies. To raise their electric efficiency, water injection systems have been applied for microturbines, such as water atomizing inlet air cooling (WAC) [1], a recuperative water injected cycle (RWI). However, the quantative contribution to generator output power augmentation which is summention of turbine output increase and compressor power reduction by injected water has not been made entirely clear.

A dynamic simulator is expected to be a useful tool to understand dynamic characteristics of the turbine system because each effect of system component can be separeted in the simulation results. The purpose of this study is to develop a dynamic simulator which can handle WAC and RWI operations and to clarify the quantitative contribution to power augmentation by the effect of water injection. Simulation results are compared with measured results which were obtained in the operation test of a 150 kW class prototype microturbine [2] developed for the first application of RWI to microturbine.

## 1. Overview of the microturbine and simulation models

Figure 1 shows a system diagram of the prototype microturbine system used for this study. The main components are a single-stage centrifugal compressor, a single-stage radial turbine, a can type combustor, a recuperator, a permanent magnet generator, and an electrical conversion system. The main feature of this microturbine system is utilization of water for improved electrical output. Water supply lines that include the WAC and RWI lines are indicated by thick broken lines. The arrangement of the main components of the prototype microturbine is shown in Fig.2. Colored arrows in the drawing show the flow of working fluid.

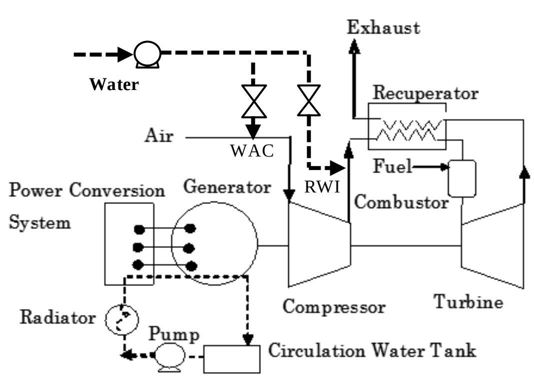


**Figure 1.** System diagram of the objective microturbine system [2]

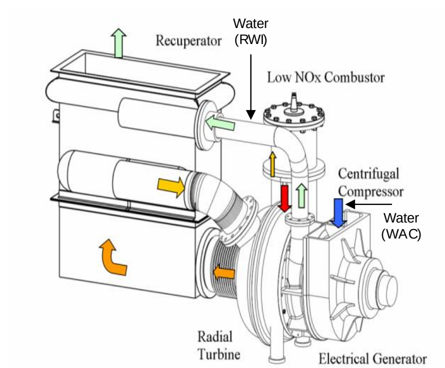


**Figure 2.** Perspective view showing arrangement of the main components of the microturbine [2]

Simulation models are composed of a conservation equation of angular momentum of the rotor, equation of the driving power of the compressor and output power of the turbine, combustion models, and some loss models such as windage loss. Effect of heat penetration from the turbine to the compressor is considered in simulation of the compressor driving power. Simulation models of a single droplet evaporation [3] are also used as those of WAC and RWI. The rotational speed of the rotor which is a control value of the turbine system operation, fuel flow rate, and water flow rate of WAC and RWI are given as the input data.

## 2. Results and discussions

Simulation results of turbine output power, the compressor driving power, and the generator output power are compared with those of the measured results [2] in Fig. 3. In the right side of Fig. 3, the power histories are engaged in the region of WAC and RWI operations. Injection water was supplied first for WAC, which was done as two pulse injections for a trial and then it was continuously supplied after the trial. During the continuous supply period for WAC, three trial pulse injections for RWI were carried out to check stability of the turbine system operation. Continuous supply for RWI was done after that. Generator power jumps which occurred at the timing of WAC and RWI operations can be captured in the simulation results. The broken lines are the simulation results without WAC and RWI.

Figure 4 shows breakdowns of the power augmentation given by the difference between the results with water injection and those without water injection. Generation output power augmentation of about 7 kW by WAC operation is obtained in the simulation due to the compressor power reduction and turbine power increase. Similar results are observed in the RWI operation. As RWI is implemented for the downstream region of the compressor, RWI is generally thought to give no effect on the power reduction of the compressor. Heat penetration into the compressor decreases because the turbine inlet temperature decreases when RWI is operated. This heat penetration reduction affects the driving power reduction of the compressor. The compressor power reduction of 2 kW and the turbine output power increase of 6 kW by RWI are obtained. Total generation output power augmentation of about 15 kW is compared to the value just before the WAC operation. These power augmentations show relatively good agreement with the measured values for the prototype microturbine operation test [2]. In the total output power augmentation of the generator by WAC and RWI operations, about one-third of that is brought about by the reduction of the compressor driving power and the remaining two-thirds is brought about by the increase of the turbine output power.

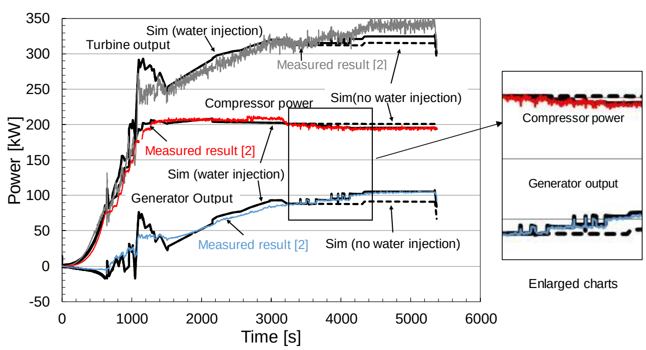


**Figure 3.** Comparison of power histories and enlarged charts

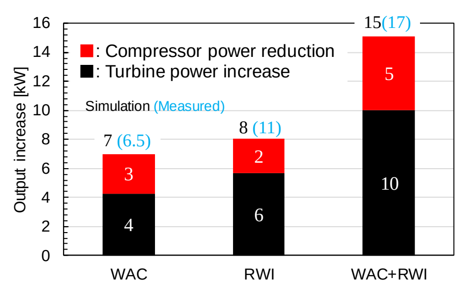


**Figure 4.** Effects of water injection

## References

[1] Williamson T., Luker M., and Hack R. L., 2005. "Microturbine performance improvement through the implementation of inlet air cooling". ASME paper GT2005-68377.

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[3] Myoren, C., Takahashi, Y., Yagi, M., Shibata, T., Kishibe, T., 2013. "Evaliation of axial compressor characteristics under overspray condition". ASME paper GT2013-95402.